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IN THE

# Supreme Court

## OF THE UNITED STATES

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October Term, A. D. 1905

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THE STATE OF MISSOURI,
*vs.*
THE STATE OF ILLINOIS
AND SANITARY DISTRICT
OF CHICAGO.

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## Abstract of Record for Defendants

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W. H. STEAD
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*of Counsel.*

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*Attorney Sanitary District of Chicago.*
JOHN G. DRENNAN,
*of Counsel.*

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Before
FRANK S. BRIGHT,
Commissioner of the Supreme Court of the United States.

Testimony begun at City Hall, St. Louis, Mo., Feb. 17,
1 1903, at 10 A. M., pursuant to order heretofore entered in said cause.

Present:

The Commissioner;

Attorney General Edward C. Crow, Charles W. Bates, and S. B. Jeffries,
On behalf of Missouri.

Attorney General H. J. Hamlin,
On behalf of Illinois.

William M. Springer, and
J. G. Drennan,
On behalf of Sanitary District of Chicago.

2 THE COMMISSIONER: My commission is now open and I am ready to hear testimony pursuant to rule heretofore entered by the Supreme Court and notice of Complainant's Solicitors.

Adjournment.

Met pursuant to adjournment at same place at 2 P. M., same day.

Present, same parties and Alexander Nicholson, also representing complainant.

AMAND NICHOLAS RAVOLD, called in behalf of complainant, after being duly sworn by the Commissioner, on direct examination by Attorney General Crow, testified as follows:

Reside at 2806 Morgan st,. St. Louis, Mo. Am a physician and have been practicing since 1881. Since 1885 have been a professional bacteriologist. Was first connected with Shaw School of Botany in 1886—was assistant to Prof. William Trelease at Washington University. In 1887 became lecturer on bacteriology in medical department of Washington University. Then known as St. Louis Medical College. Later was professor of Bacteriology in medical department of Washington University and continued so until last year when I resigned to go abroad.

3 The Washington University Medical College stands now with reference to other schools as one of the great schools of the country.

6 A non-pathogenic organism is one that does no harm to an animal, while a pathogenic organism is one that lives in his tissue and does him harm.

In 1894 I was employed by the St. Louis health department —the city government—to aid in the bacteriological work of the health department. My title was consulting bacteriologist. I then made bacterial culture experiments and did any work of that kind that came in; I carried out experiments for the department working on tuberculosis, diphtheria, typhoid, blood

and various things that came up at that time, and made diphtheria anti-toxin.

7 Bacteriology in the medical world means the study of bacteria. Bacteria are the lowest forms of vegetable life. They are closely allied to the algae. They belong to the group thallophyta, and come in the division known as schizomycetes or fission fungi. They are found everywhere on earth, on the surface of the earth, more or less on the surface or in the earth in the waters of the earth and in the air close to it, even extending up to some height, as high as they can go, as high as the currents of the air will carry them above the earth's surface.

(Gives a history of the origin and development of the science of bacteriology.)

10 Pure culture means that a micro-organism, say anthrax bacilli, are separated out and made to grow alone in the medium or upon the medium. It is free of every other micro-organism, it is a pure culture and if it is not free of every other micro-organism, it is impure culture.

11 Prior to along about 1849 or 1850 there had been no demonstration in the scientific world that showed that bacilli had any particular relation to diseases of the human body.

17 Explains the manufacture of anti-toxin for diphtheria.

22 Some bacteria are water born and others are not. Most of the bacteria can be water born for a short distance, but many of them die—very many—in water. The water born diseases as we know them are typhoid fever, the cholera and dysentery. Most of the other bacteria are in the soil or in the air.

There would be no life on earth without bacteria, consequently they are the undertakers of the organic world. By this I mean that when an animal dies or a tree falls, in a short while, as we know, that material begins to break down. After it lies awhile we see that it gradually disappears, breaks apart and finally disappears, and so with an animal dead upon the field. It swells up and stinks for a while and then disappears, leaving

nothing but bones. Now the cause of the disappearance of a tree or the meat of a dog or dead animal are the result of a destructive action of the bacteria upon the chemical compounds that compose the heterogeneous structure of that animal. They reduce, in other words, the highly complex nitrogeneous compounds and carbon compounds to the lower forms of carbon, hydrogen, oxygen and nitrogen.

23 These are the four basic forms of animal and vegetable life. These heterogeneous molecules are broken up so that in the end we have ammonia and carbon dioxide as a result. The carbon dioxide passes off in the air. Ultimately these complex heterogeneous structures are reduced to the elements from which they came. These simple compounds form the food for plants again, and the plants take up this broken material, and grow. Plants are food for animals, hence animals upon earth; so that without bacteria there would be no life upon earth. They are also the destroyers of the organic world.

24 Bacteria destroy sewage, for instance. That is, sewage in a tank is destroyed by them.

Q. Now what is it the septic tank produces?

A. It consists in running crude sewage into tanks hermetically sealed, and the bacteria there being of two kinds, aerobic and anaerobic, break up the organic compounds of the sewage. I am using crude sewage in the technical sense. It doesn't make any difference whether it is diluted or concentrated sewage. It is run into these practically hermetically sealed tanks. The aerobic micro-organisms act upon the sewage, first working in the presence of the oxygen of the air in the sewage; so soon as the available oxygen is used up, the aerobic bacteria cease their destructive action on the sewage which gives the anaerobic bacteria which flourish best in the absence of oxygen a chance to attack the organic compounds of the sewage. The result of the destructive action of these two kinds of bacteria on the sewage is to quickly liquify the solid organic materials and to reduce them to lower and lower nitrogen-

25 eous and carbonaceous compounds. Ultimately am-

monia, carbon dioxide, hydrogen and marsh gas are produced, which are gases and lower forms of nitrogen and carbon compounds which are food for plants.

I have one of these tanks in my cottage in the north. It works during the whole summer, and it works in the way I spoke of it.

Those bacteria are present in all sewage mostly.

An enormous number of bacteria in the world are beneficial, and a great many of them are harmless. There is only an occasional one that is harmful.

The bacteria that has been looked upon as the index of fecal pollution and is found in water fed by sewage, and in the stomach of animals, including man—or rather in the intestinal canal is called bacillus coli communis.

26 By fecal pollution I mean that whenever there is sewage from man or animals the bacillus coli communis is generally found present.

They are also found in discharges from man or animals on the soil or anywhere else. In some of our work we found that it does not exist in the intestinal canal of fish in the ordinary streams, but in the fish of the Illinois river it exists in very large numbers in the intestinal canal—in about 70 per cent of the fish. In the fish in ordinary streams it does not exist, but in the highly polluted water of the Illinois river we found the bacillus coli communis in the intestinal contents of the fish taken from that river.

29 Koch discovered the cholera bacteria in the intestinal contents of people sick or dead of the disease, and he found it in the water of one of the tanks in India, from which the cholera had come, from which an epidemic of cholera had spread. He put it in steriled water and also studied it in living water, and he found that it would live a definite number of days in various kinds of water. It is subject to changes of temperature—water hot and cold. It takes a temperature of boiling water to kill it. Boiling water is 100 degrees centigrade. It takes five or ten minutes. It will stand indefinite freezing—

that is steady cold; but alternate heat and freezing will destroy great numbers of the bacteria very rapidly. It is highly active —it is motile, a swimmer.

30 It increases very rapidly. Increases most rapidly in the human system. I think no experiments have shown that it multiples in the water. It will grow on all media easily? It is a water born disease. There is a possibility of taking it through the air.

31 All bacteria arrest their own destructiveness—both the injurious and non-injurious. Bacteria growing on or in a medium produce toxins and after a time when they accumulate in sufficient quantities, stop the growth of the bacteria. They do not destroy exactly, but there is not enough nutritive media left for them to grow upon, besides the toxin produced inhibit the growth of the micro-organism. A man might have diphtheria or typhoid fever, and not be free of poison, and still recover.

32 The body itself produces anti-toxin to the specific bacteria.

Q. Well, does the poison that is thrown off with this bacteria, so that a man gets well without the pure anti-toxin, does that have the effect of curing him of his disease?

A. Yes, sir. A spore is known as the resting stage of the micro-organism.

(Describes spores and bacteria and method of propagation.)

33 A spore is the most high vitalized thing on earth. Some of the pathogenic organisms form spores, the anthrax bacillus for instance. That is a highly resisting spore. Tetanus (lock jaw) has a highly resisting spore that is especially obnoxious.

Typhoid fever, cholera or diphtheria have no spores. Tetanus and anthrax are the principal bacteria having spores.

(Explains method of sand filteration in which bacteria form part of the system.)

36 These filters have proved efficient and perfect. Typhoid

bacilli will occasionally go through this. That is demonstrated by typhoid fever breaking out in a community where these filters exist.

37 A good filter, kept in proper shape at all times will stop typhoid. It will work if the individual who is using it is a skilled man and will take care of himself, but if it is left to the ordinary servant it will be in bad condition at all times.

38 Bacteria are classed into the pathogenic or non-pathogenic; those that produce disease and those that do not produce disease. The non-pathogenic are the most prevalent. A general classification shows the non-pathogenic exists in vastly great numbers.

39 The aerobic bacteria is the most active agency in the destruction of sewage in the open stream. The effect of that upon the sewage in the running water would be its gradual reduction from the higher compounds to the lower compounds.

Q. Now would that reduction affect the vitality or existence of the disease bearing bacteria in that running water?

A. Not the mere destruction of the bacteria in the water, no, but the action of the toxins of the individual bacteria upon one another is a vital problem. By that I mean this: You take bacteria confined in a space all growing vigorously and active, and each producing its kinds, and giving forth its products, these products are not only poisonous to themselves, but poisonous to other bacteria around them, and some bacteria produce poisons that are very deleterious to others. That is true of the bacteria in running water.

Q. Is it known that the injurious agencies are running and operating in the running water, and whether in that way they tend to destroy the cholera or typhoid or dysentery bacteria?

A. Now if the waters available were merely polluted, the action would be much less where the water was confined than where it was running.

Q. In this form of water there would be less liability of

the destruction of these bacteria than there would be if they were confined and the water was still?

A. Yes, they would die much quicker in stagnant water than in running water.

Q. In other words, the toxin would be much freer to have its effect?

A. Yes, sir.

41 This process (septic tank) tends to destroy typhoid and cholera germs. Also dysentery germs.

A septic tank properly constructed and maintained in a proper way would be an absolutely sure day of destroying any germ bearing bacteria in the sewage of a city, if the sewage of a city was confined exclusively in septic tanks.

There are several cities in England that have these tanks. They are experimenting with septic tanks in Massachusetts. I do not know just now of any place where they have got beyond the experimental stage.

43 Inspected the sewage system of Berlin. They have the sewage farm system. The sewage is collected in large reservoirs in the town and from these reservoirs it is pumped out on to what used to be a sandy waste. The water is pumped up into the tanks upon those places, and then distributed for irrigation all over those farms, and it lies upon the surface for a time, percolates down through the sand, and a good deal of it passes into large ditches at the side of the field and out into the water courses. The bacteria are eliminated on the fields—the sand fields, by the filtration. At top of the soil they are held and destroyed. It is a fine way to conduct a city sewage system.

44 The pollution of sewage in running water must be very great in order to cause experts to say that the water is no longer healthful to use for domestic purposes. The volume of water does not destroy the bacteria.

45 My experience would be, and I believe the fact to be that the disease bearing germs that flow away from a city in

the sewage of that city would be borne mostly from the homes of the city where the disease existed.

46 Epidemics of typhoid and cholera and dysentery are usually caused, or believed at least to be caused, by the water born micro-organisms, which means a tainted water supply. That is true in this country at this date. The most common disease bearing bacteria that is born in the water of this country is typhoid. The reason for this is because crude sewage is discharged into the water closets, and water closets discharge into sources of water supply. Crude sewage is sewage that is not treated—disinfected.

47 Cholera germs live in the Mississippi river here, in the sunlight and dark, from 12 to 25 days.

If the Mississippi river had cholera germs in it and it should freeze over, it would not hurt them. It would not hurt typhoid fever germs.

In 1892 an epidemic of cholera was caused at Hamburg, Germany, from the dejecta of Jews suffering with the disease which was thrown in the River Elbe, that river being used as a source of water supply for Hamburg.

49 My experiments lead me to believe that typhoid bacteria will live in Mississippi river water here at St. Louis in the sunlight as high as eight days and in the dark as high as 21. That is living water.

50 The scientists of the Massachusetts state board of health found that they (typhoid bacteria) would live 25 days in the water of the Merrimac, in experiments at Lawrence and Lowell.

Q. Is there any other place where they have ever experimented?

A. Yes, throughout the literature, quite a number.

Q. What would be the average time?

A. About that time—from a few days to as high as 25 and 30 days, and always longer in steriled water, of course.

The effect of the sand filters at the places where I observed them, in London and other places, was to diminish the amount

of typhoid and other diseases from the water-born bacteria.

Have had no experience with any typhoid epidemic in this country other than in the city of St. Louis. That was in 1892 prior to the time that the present intake was placed at its present existing spot. The intake was then at Bissell's Point. The present intake I suppose is six or eight miles above that on the river. Both on the Mississippi river. I do not know the width of the river at the present place of the intake. It is fourteen miles above the city, I think. Six or eight miles below the confluence of the Missouri and the Mississippi rivers. The division of the waters at the confluence of the two streams is quite perceptible. At the intake if the Missouri river is very high it can be very distinctly seen at the intake. Its great volume of
53 yellow water runs down clinging to the Missouri shore, and can be seen. If the Mississippi is high and the Missouri not high, the effect of its waters can be seen at the intake.

Q. Well, if the Mississippi is very high and the Illinois is very high and the Missouri is not, what effect has that on the volume or character of the volume of water that comes over to the intake and into the waterworks?

A. Well, as a rule under those conditions the Missouri predominates.

Q. Where the Mississippi is high?

A. Not where the Mississippi is high.

Q. I mean where the Mississippi is high and the other two are low, in ordinary stages?

A. Then the waters exist in about equal quantities, or the Mississippi water may predominate. It appears that way to the naked eye.

Q. Now you stated that the bacteria in the water at the intake tower, when you cross sectioned the river there, would indicate the presence of more than one stream?

A. Yes, sir.

Q. What is there in the indication of that bacteria that indicates that to a scientific investigator?

A. Well, we know the numbers of bacteria in the Missouri river before it enters the Mississippi; we know the numbers of bacteria in the Mississippi above the junction with the Missouri river, and that these two streams flow down together, the Missouri clinging to the Missouri shore, the Illinois and Mississippi rivers combined, clinging to the Illinois shore, now the cross section of the stream will show whether the greater number of bacteria are on the Missouri side or on the Illinois side; then we can finally reach the point where we can see the two streams are about to touch one another, or commingle.

Q. Now you use the term "bacteria" without regard to whether they are injurious or non-injurious?

A. They are non-injurious.

Q. That is, they are simply indigenous to running water?

A. Water born. They are found everywhere in the
54 water of these two streams. They are the same bacteria.

Q. Is there anything to indicate after the Illinois enters the Mississippi below the mouth, the presence of the Illinois river, in the Mississippi river water?

A. No, sir. The bacteria of the Illinois are very similar in numbers and character to those in the Mississippi, and it is only by putting different kind of bacteria in the Illinois river and watching them as they flow, that we can trace the Illinois river water, species of bacteria that are not indigenous to either stream.

As to the waters, a visual inspection will show that samples from the Illinois and Mississippi are of a less muddy color, and contain less sediment than the samples from the Missouri in the greater part of the year.

55 My impression was that the Mississippi above the Illinois is more rapid than the Missouri above the Illinois. That is in equal stages of water. The more rapid the stream the further the bacteria carry. I think the Missouri would sediment its bacteria much quicker, because the sediment in the stream is very much larger. All inorganic particles are larger

and would carry down the bacteria in the water very much more rapidly than the Mississippi river will.

Q. What would be the result of that on the number of bacteria the non-injurious bacteria, that are just useful water-born bacteria, in the two streams, in the same volume of water? Both running at about equal speed?

A. For some reason or other the Missouri has the larger number.

Q. Now they are non-pathogenic, are they?

A. Yes, sir, a great majority of them.

56 The sand in the soil above the mouth of the Missouri river, contains large numbers of bacteria. I am speaking of the Missouri. They were alive.

Q. Now, are they non-pathogenic?

A. A great majority of them.

Q. Harmless?

A. Yes, sir.

Have examined at the confluence of the two rivers, the soil and the sand in the bottom of the Mississippi. Found a large number of bacteria, a very large number.

Q. What was the character of these bacteria?

A. Mostly harmless.

Q. Now do you know anything about the proportion of the bacteria in the two rivers and the sand and soil on the bottom of the two rivers at the point I mention, the confluence, as to which has the greater number of bacteria?

A. Practically about the same.

Q. Could you distinguish between the pathogenic and non-pathogenic bacteria?

A. What do you mean?

Q. Why in counting these bacteria that you discovered in your examination, in your estimate of the two rivers, or in the waters of the two rivers?

A. Not without separating out each individual bacterium to get it as a pure culture.

Q. Have you done that?

A. I have separated out different varieties or different species found in the rivers, the Missouri, the Mississippi, and the Illinois, at Peoria and Grafton.

Q. Well, by this method of separation then, the numbers of pathogenic and non-pathogenic bacteria could absolutely be determined?

A. Yes, sir, but not absolutely. It would be a slow process, a gigantic task.

Adjourned.

Met pursuant to adjournment at Southern Hotel, at 10:00 A. M., February 18, 1903.

Present, the Commissioner and same counsel.

I am familiar with what is known as the Chicago Drainage Canal.

59 I know that Lockport and Joliet and Peoria—most of the towns along the (Illinois) river that have a sewage supply whatever, discharge the sewage into the river.

65 I am familiar with the St. Louis intake—that is the place where the water supply for St. Louis is taken.

66 In the Mississippi river, on the Missouri side of the Mississippi river, 1500 feet from the shore is built a large tower of stone. Connecting with that tower there is a tunnel in the bed of the river to the shore. It runs alongside of what is known as the Chain of Rocks, which were put out there to deflect the flow of the river away from the Missouri shore. The water passes down through openings in this tower into the tunnel; from the tunnel it runs into what is known as the uptake and reservoir and from there to the pumps or to the reservoirs, six in number. After settling in these reservoirs the water is allowed to rest in these reservoirs from 24 to 48 hours, generally 36 hours. It passes out into a conduit and is carried to St. Louis. On the way it meets the pumps at Baden. The high service pumps there pump the water into what is known as the high surface tower which is located on Grand and La Fayette avenues. From there it is distributed throughout the west-

ern part of the city, and the high portions of the central portions of the city. The remaining part of the water passes on to Bissel Point, and there passes into reservoirs, and rests for a time in the reservoirs, to pass from the reservoirs into a series of low service pumps which supply all this part of the city, the low part of the city, the central part of the city.

67 I think it is six miles from the settling basins to Baden and eight miles to the low service pumps or low service reservoir at Bissell Point. From Baden to the high service reservoir I suppose it is 3 or 4 miles. The distance from Baden to where the low service basins are located is two miles. The tunnel that runs from the tower in the river to the shore I think is an eight foot tunnel. That tunnel is walled with stone and brick.

68 The settling basins are very large. The tower in the river is in the main channel of the Mississippi river. I do not know exactly the width of the river at that point. In the ordinary stages of the river I would say it was a mile across.

It is eight miles from the water tower in the river to the point of conjunction of the Mississippi and the Missouri rivers. It is 25 miles to the conjunction of the Illinois and the Mississippi.

At the intake of the St. Louis Water Works there are no filtration plants or processes anywhere that the water passes through or over between the time that it enters the tower in the river up to the time that it goes out in the service pipes. The subsidence that occurs while the water is resting in the reservoirs at the Chain of Rocks is the only treatment whatever that the water receives.

All fecal matter of a man or animal contains what is known as bacillus coli communis.

Fecal matter is the intestinal contents discharged from man, from the bowels of man and animal.

This bacillus coli communis is found in animals and also in fish.

I have been unable to find any reference whatever that shows that it has been found in fish prior to my investigation.

We found the bacillus coli communis in the waters of the drainage canal, the Des Plaines river, the Illinois and Mississippi.

69 The finding of bacilli coli communis is looked upon by bacteriologists as the index to fecal pollution, for the reason that whenever these micro-organisms have been found in water, the conclusion is reached that the water must contain sewage, either from the intestinal contents of man or animals. It is an indication of sewage in water.

There are several other bacilli that are found in running streams that are an indication also of sewage in water. But there really is no good index. There are micro-organisms that are found in sewage steadily wherever sewage is present, but a true index to fecal pollution, I don't know a single one.

Q. Now do you mean to include in that statement the bacilli that we have been talking about?

A. Yes, sir, that is, previous to our work upon the intestinal contents of fishes, these micro-organisms were really looked upon, and I believe it is still by Prof. Jordan, looked upon as an index to fecal pollution, but our own experi-

70 ence robbed it of that dignity.

The reason for this is that if it is found in a stream steadily, and we know that fish in the stream at the same time, not only have had in their intestinal contents and have it in there, and are discharging it from their intestines, then the bacilli coli communis found in that particular water may be either from sewage, from man, or from animals, or fish.

We have found it in fish in the Illinois river. Also in carp in the Mississippi. Am not sure whether I found it in the fish of the Missouri river—I think not.

Whatever fish we found in the canal, the drainage canal, were dead. We didn't go into their intestinal contents at all. They were killed by the fact that the aerobic micro-organisms which are present in water polluted by sewage, consumed

71 the oxygen that was in the air in the water. That leaves the water without air for the fish to breathe, and having no air to breathe, they die.

The cause of the presence of large numbers of these aerobic micro-organisms was due to the fact of sewage in the water.

Don't know whether there are any fish in the Des Plaines river. Saw men fishing there. Examined 68 fish in the course of several months in 1900—1899 and 1900.

Was consulting bacteriologist for St. Louis in July, 1899. Health Commissioner was ordered by a motion made in the city council, to have investigations made, and I was assigned to the work.

72 Suit was begun 22d of January, 1900. Had made investigation of the waters of the Mississippi and Illinois between that date and July, 1899, and the drainage canal. *Began work August 10, 1899.* Consisted in taking samples from the water at various points, in four ounce bottles.

73 The examination made was of a bacteriological nature. The water was taken with a special apparatus designed by me, in sterile vessels, from about 3 feet below the sur-

74 face of the river.

Sterilizing may be done by three methods. (Methods explained.)

75 Constructed special apparatus for taking samples.

76 There are particular rules or methods adopted generally by bacteriologists in this country, in the examination of water and other things for the discovery of bacteria.

The American Public Health Association—the bacteriological committee, have published a report in 1898 and is called "Procedures recommended for the study of bacteria, with special reference to a greater uniformity in the description and differentiation of species. Being a report of a committee of the American Bacteriologists to the committee on pollution of water supplies of the American Public Health Association, submitted at the meeting of the Association in Philadelphia, September, 1897, published by the Rumford Press, 1898."

This report made part of the record that outlines the method that is approved by bacteriologists generally.

At a meeting in 1901, a few minutes were made in some of the details or media.

77 We collected samples at the intake of the St. Louis water works. We immediately plated them.

We followed the method laid down in that volume for the preparation of media throughout, by plating I mean we mixed a definite quantity of the water from the sample with the media in a tube and poured it out in a petri dish. This was put in the ice chest, kept at a temperature of 20 centigrade about 60 Fahrenheit, and the bacteria allowed to grow for two or three days, and the colonies of bacteria which have formed are counted. Each colony is considered one bacterium. The number is then recorded. Now for each sample of water we made from two to three plates. The result of these investigations simply gives the unclassified number of bacteria.

Besides that we carried out some work identifying the number of bacilli coli communis in sterilized water collected at these points.

These collections were made at the Mississippi river just above the intake of the St. Louis water works, August 10,

79 and Aug. 30, 1899. Two plates were used of each sample.

The results shown are the mean number of bacilli on the two plates at each point, per cubic centimeter of all kinds.

80 Mississippi river just above the intake,

August 10, 275 bacteria,

August 30, 275 bacteria,

September 12, 650 bacteria,

September 13, 1500 bacteria,

September 15, 2300 bacteria,

September 16, 1700 bacteria,

September 20, 1200 bacteria,

September 25, 3600 bacteria,

Illinois side of the intake, toward the Illinois shore directly in line with the intake, on August 23d, the number of bacteria was 240.

In the intake, as the water flowed into the intake,

August 10, 500 bacteria,
August 21, 375 bacteria,
August 22, 950 bacteria,
August 23, 550 bacteria.

After this water had flown from the river and discharged into the uptake, a sample of water was taken from the uptake. From the tower to the shore is a tunnel, and when it flowed out of the end of the tunnel, 1500 feet from the river, a sample was taken there. As I say, we found no difference in the numbers in the intake and the uptake, as you see:

(Following is all uptake)
August 10, 600,
August 11, 650,
August 12, 650,
August 14, 650,
August 15, 1500,
81 August 17, 750,
August 18, 650,
August 19, 400,
August 21, 325,
August 22, 150,
August 23, 1300,
August 24, 475,
August 25, 400,
August 26, 275,
August 28, 275,
August 29, 170,
August 30, 300,
September 4, 300,
September 5, 270,
September 11, 300,

Made six boat trips up the river between August and January 23d. Up the Mississippi to the mouth of the Missouri.

In the Illinois as far as the brick house club, 5 or 6 miles up the river and 2 or 3 or 4 miles up the Mississippi above the conjunction with the Illinois river, and samples were collected at different points between those.

82 We took 32 samples. Colon basillus in the presence of sugar produces fermentation, it breaks up the sugar, producing gases. Now if we can put sugar broth into a U tube known as a fermentation tube, and have the glass arm filled with broth and the open arm so that we can throw water into it, if the bacillus coli communis is there, it will break up that sugar and form gases in the glass tube. The gases form at the top and force the water down. It produces as a rule about 60% of gas in the tube, so when we put a small quantity of water in the fermentation tube and collect about 40 to 60% gas, sometimes 75%, we know there is gas-producing bacillus there, and then we merely search for this gas producer by plating and studying the colony characteristics of the micro-organism that we think produce this gas. The micro-organism is picked off and showed on a variety of media, its microscopic form and motility studied.

Motility means whether it swims in fluid or not.

This is not the character of coli work that was carried on on these boat trips, altogether. Samples were returned to my laboratory in the city chemist's office, and there these experiments were carried out.

Result of examinations, number of unclassified bacteria, is as follows:

83 September 6, Illinois river, Wheeler's ferry, 3 miles above the mouth, 130 bacteria.

Illinois river, five miles above the mouth, at Grafton, what is known as Brick House club, 170 bacteria.

Illinois river, 7 miles above Grafton, 6 mile Island, 160 bacteria.

Following is Mississippi river:
September 6—all on same day.
Opposite Grafton, 190 bacteria;
4 miles above Grafton, 550 bacteria;
6 miles above Grafton, 276 bacteria.
Above plated on harbor boat after collection.
September 9th:
Mississippi river as follows:
Chain of Rocks, 160 bacteria;
Madison Landing, above mouth of Missouri, 210 bacteria;
1½ miles below Alton, in the channel, 190 bacteria;
1 mile above Alton, 240 bacteria;
1 mile below Grafton, 160 bacteria;
Opposite Grafton, 150 bacteria;
Missouri river, near mouth, 180 bacteria;
Illinois river, just above Grafton, 90 bacteria.

Bacteriologists mark a bacillus coli communis positive or negative. They mark it with a cross if the bacillus coli is present, and if it is not present, it is marked "minus." Zero means sample not examined for coli. By the word "present" I mean that it was a positive reaction; that it showed the coli communis were present in the sample. I found bacillus coli communis in it. (The letter B indicates the word "Bacteria.")

September 16:
Mississippi river, Chain of Rocks, 1700B;
84 Mississippi river, Madison Landing, 800;
Missouri river, near the mouth, 2600;
Mississippi river, 2 miles above mouth of Missouri, 700B;
Mississippi river, 1½ miles below Alton, 800B;
Mississippi river, 1 mile above Alton, 700 B.
September 21:
Illinois river, 1½ miles above Grafton, 450B;
Illinois river, 3 miles above Grafton, 400B;
Illinois river, 5 miles above Grafton, 425B;
Mississippi river, 1 mile above Grafton, 500B;

Mississippi river, 4½ miles above Grafton, 500B;
September 25:
Mississippi, Chain of Rocks, 3600B;
Mississippi, Madison Landing, 750B;
Missouri river, just above mouth, 5600B;
Mississippi river, half way between Alton and mouth of Missouri, 750B;
85 Missouri river, opposite Clifton, 750B;
Mississippi river, half mile below Portage, 600B;

Between September, 1899 and January 23, 1900, no bacteriological investigations were carried on by me to determine the presence of bacillus coli communis in the Mississippi or Illinois, other than above mentioned.

Above testimony is in regard to work done from August, 1899 to January 23, 1900, under my personal supervision, I doing the coli work personally, media made in my office, plating done at the Chain of Rocks.

Drainage Canal was opened six days prior to January 23, 1900.

Bear trap Dam was lowered January 17, 1900.

89 Beginning January 23, 1900, pursued bacteriological investigation in the waters of the Canal, Lake Michigan, the Illinois, Des Plaines and the Mississippi rivers.

90 Took samples of water from various points, studied it for its bacteriological points, that is the number of bacteria per cubic centimeter, for the detection of bacillus coli communis, and the study of the bacteriological flora of the water—that is the different species found in it.

Following are distances from St. Louis intake to points named:

Lake Michigan, 357 miles;
Lockport, 327 miles;
Joliet, 320 miles;
Peoria, 196 miles;
Grafton, 39 miles;

Alton, 23 miles;
Hartford, 12 miles;
All above towns are in Illinois.
Bellefontaine on the Missouri river, 14 miles.

92 Lowering of the dam at Lockport and the working of the pumps at Bridgeport changed the flow of the Chicago river—reversed it.

I collected samples of water daily at Lake Michigan, Lockport, Joliet, Peoria and Grafton, beginning 23d of January, 1900.

93 Our instructions were to take it from the channel where the water flowed the most rapidly and deepest, three feet below the surface with the apparatus designed by us.

Water was taken in Chicago at the four mile crib, Carter Harrison crib, ten miles from the Chicago shore, Lakeview, three mile crib, four mile crib, 68th street, four mile crib. The cribs are intakes for Chicago water supply:

Following is the time taken, place, number of bacteria, etc.
July 23d, 4 mile crib, 11:45 A. M., 1,600B.

94 Carter Harrison crib, July 30th, 11:30 A. M., 1900, 12,300B, ten feet below surface.
Ten miles from shore, ten feet below the surface, Aug. 9, 4 P. M., 16,300B.

95 Carter Harrison crib, 31st of August, 10:30 A. M., 21,400B.
Lake View crib, Sept. 7, 11:30 A. M., 5,200B.
Two mile crib, Sept. 15, 10:30 A M., 909,700B.
Three mile crib, Sept. 15, 11:45 A. M., 111,500B.
Two mile crib, Sept. 22d, 2 P. M., 61,000B.
68th St., Sept. 22d, 11:15 A. M., 44,000B.
Two mile crib, Sept. 28, 10:45 A. M., 11,300B.
Lake View crib, Sept. 28, 12:15 P. M., 3,100B.
Two mile crib, Oct. 11, 12:15 P. M., 1,100B.
Three mile crib, Oct. 11, 11:30 A. M., 1,000B.
Two mile crib, Oct. 19, 11 A. M., 4,400B.

Two mile crib, Oct. 19 11 A. M., 4,400B.

Three mile crib, Oct. 19, 10:30 A. M., 1,100B.

96 Four mile crib, Oct. 26, 11:45 A. M., 90,000B.

68th st. crib, Oct. 26, 12:30 P. M., 157,500B.

68th st. crib, Nov. 9, 11:30 A. M., 3,300B.

Four mile crib, Nov. 9, 11 A. M., 2,900 B.

Sample taken Oct. 11, at the two mile crib and contained organisms of bacillus coli communis—bacillus delicatulus, bacillus fluorescens incognitus; bacillus helvolus; bacillus proteus mirabilis; bacillus pyocyaneus; bacillus stellatus bacillus superficilis; bacillus viridis.

All these bacteria are harmless except the bacillus coli communis—except when injected beneath the skin. It is harmless in the individual except when it goes down into the appendix and causes appendicitis. Mucous membrane of the appendix is very delicate.

97 All these bacteria other than the bacillus coli communis are inhabitants of fresh water, both lake and river. Their presence other than the coli does not indicate the absence or presence of sewage.

Next examination was made on the Drainage Canal at Bear Trap Dam, March 3, and continued daily until October 9, 1900. And from September 26 to November 25, 1901.

There was a very great bacteriological variation or fluctuation in the examinations at this point. It ran from millions of bacteria per cubic centimeter down to a few thousand. This depended on the amount of sewage from Chicago dis-

98 charged in the canal.

During the first period of time above stated, this examination disclosed the presence of coli bacillus. This bacteria was found in 87 per cent of the samples collected.

In March, 1900, it was found in 72% of the samples. May, June and July, 87%. Aug., Sept., and October, up to the 10th, 100%.

From Oct. 5, to 27, 1901, 81.2%.

Made a microscopical examination of the waters of the canal at this point. Samples were submitted to Mr. Johnson and to Mr. George C. Whipple, of New York.

We separated out a number of micro-organisms at these different periods. Inasmuch as bacteria belongs to the vegetable kingdom, we speak of the bacteria found in water as
99 the basterial flora of that water. It means the class of schizomycetes, order thelophyta.

Four sets of ten organisms each and 80 at another time, were found at Bear Trap Dam. Sets of samples were collected Sept. 16, May 31, June 14, and July 9, 1900. Eighty organisms were isolated from the water during the months of October and November, 1901.

Second investigation was from March 3, to Oct. 11, 1901.

Following is water taken from the Chicago Drainage Canal before the water passed over the Bear Trap Dam at Lockport, Illinois. (See table.)

"Not found," and "absent" means the same thing; it
107 means that in examining a quantity of water that we did not detect the presence of the bacilli. It does not mean that it was not there, but it means that they were unable to find it.

An examination of a biological character, of the water in the Des Plaines river at McDonough street bridge, Joliet, which is in the body of the city. Some of the sewage from the penitentiary and from the iron works comes in above this point. This was made from March 3d, until October 24, 1900.

The bacillus coli communis was found in 73% of the
108 samples collected daily at McDonough street bridge in the five months, March to July, inclusive. This organism was found in 64% of the examinations made. In August 78%; Sept. 1st to October 9th, inclusive, 99% of the time.

The third period, or the Ruby street bridge, 83.3% of the time, and at Brandon's bridge, also in Joliet, 79.2% of the time. That was in the third period.

The third period extended to Oct. and Nov., 1901.

109 The results March 3, at Des Plaines river, McDonough street, Joliet. (See table.)

114 On the 17th of Oct., determination made, 16,000 coli present; Oct. 24, 146,000 coli present.

115 Made examination as to the bacteria flora and located 17 distinct species—isolated, as follows:

Albus; aquatillis, sulcatus No. 1; aquatillis sulcatus No. 5; cloacae; coli communis; delicatulus; fleuresens tenuis; helvolus; iridescens; lacti viscosus; liquefaciens; ocracous; proteus mirabilis; proteus zenkeri; stellatus; superficialis sarcina lutea.

These were found during the investigation of 1900. Next point material was collected was at Peoria, above Peoria, 120 miles from Joliet.

Peoria is on the Illinois river, which is formed by the
116 joining of the Des Plaines and Kankakee rivers at a point 23 miles below Joliet. At La Salle, 102 miles below Chicago, the Vermilion river comes in and the Illinois and Michigan canal. Investigation was made at Averyville, below Peoria.

118 There was a great variation as to the number of bacilli at Peoria. They seemed to fluctuate somewhat during the seasons, to very high numbers at the Bear Trap Dam. There seems to be a perceptible rise in the number of micro organisms at Peoria at this period. Coli bacillus was found in 75% of the daily tests made. Samples were taken in the stream where the current was running fastest. This was the second period
119 beginning January 23, 1900, to October 9, 1900. (See Table.)

126 Examination made at Grafton, Illinois, 163 miles below
127 Peoria. From January 23, to October 9, 1900, two miles above Grafton. (See table.)

134 Bacterial flora of the Illinois river just above Grafton, Illinois—species: (See Rec. 134.)

Quantitative examination of Mississippi river, 3 miles above Grafton. (For result see table and Rec. 135.)

143 Bacterial flora of the Mississippi river just above Grafton, Ill.

144 Samples taken from Mississippi river, one mile above Alton, below the mouth of the Illinois river.

Coli bacillus was found in 52% of the tests made for it in this period.

Result of quantitative examination of waters of Mississippi river at above point. (See table and Rec. 145.)

Bacterial flora found in the Mississippi river one mile above Alton.

Hartford is in Illinois, 7 miles below Alton and one mile

153 above Missouri river where it empties into Mississippi.

Bacteriological examination made at Hartford, Illinois. A boat was sent out in the middle of the stream and samples collected. Coli bacillus was found in 61% of the daily samples collected. This is a slight increase over the average in which this organism was found at Alton—52% at Alton and 61% here.

The results of the quantitative determination of bacteria in the Mississippi river opposite Hartford, Illinois, together with the results of tests for the bacillus coli communis, was as follows: (See table. Also Rec. 153.)

Bacterial flora of the Mississippi, opposite Hartford, Illinois, 1900.

161 Bellefontaine is situated on the Missouri river, six miles above the mouth, on the Missouri shore—the south shore. Result of examination made there is as follows: (See table and Rec. 161.)

168 Bacterial flora of the Missouri river opposite Bellefontaine, Missouri, covering the period from January 24, to October 25, 1900, as follows:

Three separate examinations were made at the Chain of Rocks, known as the Missouri shore, the intake, and the Illinois shore. Missouri shore was taken about 300 yards from the shore in the channel on the Missouri side of the stream.

169 The intake sample was taken from a boat out in front

of the intake, just above it. The third sample was taken in a line with it over toward the Illinois shore.

Bacilli coli communis was found in 58% of the daily samples collected at the Missouri shore.

Following is result of the quantitative determination of the bacteria in the Mississippi river water near the Chain of Rocks near the Missouri shore, together with results for the tests of the bacillus coli communis—bacteria per cubic centimeter: (See table and Rec. 170.)

175 Bacteriological character of the Mississippi river water at the Chain of Rocks near the Illinois shore, about 300 yards from the shore, in the channel. The coli bacillus was found in 68% of the samples collected at this point during this period. (See table and Rec. 178.)

186 Coli bacillus was found in 62% of the daily samples taken at the intake at the Chain of Rocks.

Bacteriological examination of the water is as follows:

194 Bacteriological flora of the Mississippi river at the intake tower:

195 Samples of water were collected for analysis from basin No. 3, the water having rested 70 hours. This basin has a capacity of 29,000,000. Quantitative determination of sample from reservoir, Chain of Rocks, varies somewhat. Each reservoir has a capacity of 29,000,000. There are six of these basins.

Average number of bacteria in samples collected during the second period was 56% of the number found in samples collected at the intake tower. 44% of the bacteria in the water taken into the reservoir, therefore, were removed by this

196 70 hours subsidence—by this sedimentation. We don't care to say anything about the third period at all.

When the water goes into these reservoirs it is not absolutely quiescent, but it is the water flowing from one end of the large reservoir to the other in 70 hours. The only movement of the water is that caused by it flowing into and on through the reservoirs. The time it is in transit across the reservoir would be about 70 hours.

When I refer to the intake tower, I refer to samples taken just above the intake tower. At that point the coli bacil-
197 lus was found in 65% of the daily samples collected. That is inside the tank in the reservoir, after 70 hours sedimentation. Results of quantitative determination of bacteria in samples of water collected from the reservoir at Chain of Rocks, as follows: (See table and Rec. 197.)

204 Water was collected at the old city hall, from a tap. The city hall is on 11th street, between Market and Chestnut streets. It gets its supply from these reservoirs.

Water from the Mississippi river at the Chain of Rocks passes through the settling basins, then through an 11 foot conduit to the high service pumps at Baden, which is situated 4½ miles from the Chain of Rocks. Then it is pumped into
205 the stand pipe located at Compton Hill reservoir, and distributed to the western part of the city, while the remainder flows through a 9 foot conduit and empties into four reservoirs at Bissell's Point. Each reservoir has a capacity of 15,000,000 gallons, and while the actual periods of subsidence of the water in these reservoirs can not be ascertained definitely, it is stated to be three or four days on the average. No samples were collected from these basins. We did that in the later period. From these reservoirs the water passes into the distributing system of the city. The water is turned into the stand pipes at the foot of Grand Avenue, and distributed to the eastern part of the city in which the old city hall is located. That is the low service pumps.

It is 3 miles from the city hall, as the crow flies, to Bissell's Point, and from there it is here recorded, the distance, I just gave you, 4½ miles from Baden, and so many miles from Chain of Rocks. This is northwest of the city.

During this period the average percentage removal of bacteria, found on comparing the results obtained from samples collected at the intake of the St. Louis water works,

Chain of Rocks and the tap in the bacteriological department of the old city hall, respectively was 90 per cent.

206 That is 90 per cent of removal from the intake between those points.

The bacillus coli communis was found in 71 per cent of the samples collected during the period from May 1st to October 31st, 1900.

Results of quantitative determination of bacteria and results of tests for bacillus coli communis from samples taken at the old city hall, 11th and Market streets, beginning May 11, when we moved into this laboratory, together with the results of tests for bacillus coli communis per cubic centimeter: (See table and Rec. 206.)

211 Bacterial flora of water taken from the tap of the bacteriological laboratory, old city hall, St. Louis, Missouri, May to October, 1900.

In July, 1901, a motion was adopted by the Municipal Assembly ordering a third investigation of the city water

212 supply to be taken. This period of investigation embraced the work done between August 26 and December 1, 1901.

Temporary bacteriological laboratories were established and equipped with the necessary apparatus at the following points:

First, at Joliet, Illinois, 306 N. Joliet st., under Dr. W. C. C. Kirchner.

330 Second, Y. M. C. A. bldg., Peoria, Illinois, Dr. Wm. H.
386 Rush in charge.

Third, at Grafton, Illinois, in the Dempsey House. Mr. Leon G. Tedesche, in charge.

1141 Market st., St. Louis, with 5 assistant bacteriologists, under charge of witness.

Samples were collected from the following points:

Des Plaines river, above Lockport, from October 5, to November 25, 1901. That sample was collected about two

miles up the river, above its junction with the drainage canal so there would be no backwater in it.

213 Drainage canal, Bear Trap Dam, above dam, September 25, to November 25, 1901.

I. & M. Canal, 9th St. Bridge, Lockport, Illinois, September 25 to October 30, 1901.

Drainage canal, 9th St. Bridge, Lockport, Illinois, October 2 to November 26, 1901.

Drainage canal below Rubey St., Joliet, September 25 to November 26, 1901.

Drainage canal, Brandon's Bridge, Joliet, September 25 to November 26, 1901.

Illinois river, what is known as Shady Beach, about 3 miles above Peoria, Illinois, October 1 to November 27, 1901.

Illinois river, above railroad bridge, Pekin, Ill., October 1 to November 27. This station is five miles below the lowest Peoria sewer.

Illinois river, Kingston, 3 miles below Pekin, Ill., October 4 to November 27, 1901.

Illinois river, 3 miles above Grafton, Illinois, October 4 to November 27, 1901.

Mississippi river, two miles above Grafton, Ill., October 4 to November 30, 1901.

Mississippi river, one mile above Alton, Illinois, October 5, to November 30, 1901.

Mississippi river, opposite Hartford, Illinois, October 5, to November 30, 1901.

214 Missouri river, opposite Ft. Bellefontaine, October 4, to November 30, 1901.

Mississippi river, Chain of Rocks, near Illinois shore, September 14 to November 30, 1901.

Mississippi river, Chain of Rocks, near the Missouri shore, September 14 to November 30, 1901.

Mississippi river, intake tower, September 14 to November 30, 1901.

Reservoir at Chain of Rocks, September 15 to November 30.

Reservoir, Bissell's Point, September 16 to November 30.

Tap laboratory, 1141 Market st., St. Louis, September 17 to November 30, 1901.

Tap, residence, 5946 Garfield avenue, Oct. 2 to November 30, 1901.

Seven samples were collected at La Salle, Ill., from the Illinois, and 24 at Beardstown, Ill. Both samples were sent to Peoria, packed in ice for analysis.

Mr. Randolph, chief engineer of the Sanitary District, constantly spoke to me of the Des Plaines river between Lockport and Joliet as being the canal—the drainage canal.

215 Des Plaines river at Lockport, 2 miles above its junction with the drainage canal water, there were forty samples taken.

Drainage canal, Lockport, above Bear Trap, 52 samples were collected.

216 Illinois & Michigan Canal, Lockport, 9th st. bridge, 34 samples.

Drainage canal, 9th st. bridge, Lockport, 41 samples.

Drainage canal, below Rubey st., Joliet, 6 or 7 miles from 9th st. bridge, 51 samples.

Drainage canal, Brandon's bridge, 49 samples.

Brandon's bridge is 40 miles below this Rubey street sample, so that would be about 12 miles from the drainage canal.

Illinois river, Shady Beach, above Peoria, 54 samples. That is 120 miles down the river. About 3 miles above Peoria.

Illinois river, above railroad bridge, Pekin, Ill., 57 samples. It is ten miles from the center of Peoria to the center of Pekin. It is five miles below here—below the last sewage discharge from Peoria into the Illinois river.

217 Kingston, 3 miles below Pekin, 55 samples.

Illinois river, three miles above Grafton, 56 samples.

Mississippi river, 2 miles above Grafton, 56 samples.

Mississippi river, 1 mile above Alton, 52 samples.

Mississippi river, opposite Hartford, 51 samples.

Missouri river, opposite Ft. Bellefontaine, 55 samples.

Mississippi river, Chain of Rocks, Illinois shore, 74 samples.

Mississippi river, Missouri shore, 72 samples.

Mississippi river, intake tower, 70 samples.

Reservoir, outlet screen chambers it is called, Chain of Rocks, 75 samples.

Outlet screen chamber is located about the middle of the end of the reservoir, facing south, and the water discharges out of this hole in the wall through a screen, and consequently they call it the outlet screen chamber. About 300 or 400 feet

from the Mississippi river.

218 Bissell's Point, 72 samples.

Tap laboratory, 1141 Market st., 69 samples.

Tap, 5946 Garfield avenue, 59 samples.

Illinois river, La Salle, 7 samples.

Illinois river, Beardstown, Illinois, 24 samples, making a total of 1,215.

The work during this period was done under my supervision.

Samples collected from the canal at Lockport and the river at Peoria were taken at once to the laboratory, placed on ice and plated without delay. This is true of all of these samples that were collected at points where laboratories were established. In St. Louis a room was secured from the water commissioner at the Chain of Rocks pumping house, and there the samples were collected in the river for the Chicago experts—a Chicago and a St. Louis bacteriologist, at the same time and place, brought ashore and both bacteriologists plated in this same room, so they were plated immediately there when they came ashore. Facilities were furnished by the city at time of taking these samples. I believe Chicago paid for some of the

heat.

218 The samples were just brought to the laboratories of both

parties, brought to 1141 Market st., by Mr. Damon, who did this plating at the laboratory of the Chicago expert, some-

where on Locust street, both going in and out together.

219 These samples were collected by both parties at the same place—they went out together. They were collected with an apparatus designed by myself in wide mouthed, sterile flasks, at 3 feet below the surface. Same manner and same apparatus were used as were used in second period. The temperature of the water and air were taken at the same time with a thermometer that was a part of the apparatus; 2,325 samples were collected at the various points noted above. and analysis for quantitative determination of bacteria and tests made for bacillus coli communis.

We also investigated the bacterial flora of the water. Besides that a systematic study of the flora was made by an expert microscopist, Mr. George C. Whipple, of Brooklyn, N. Y.

We separated out eight sets of ten organisms each—separated out in pure culture, and 80 organisms in each station.

The sample collected once or twice a weak, was plated according to the method described in the first period, and then ten organisms were selected from that plate, always trying to select an organism that was new to the bacteriologist. He selected the first ten that were familiar to him and the next time he went over that plate he tried not to select any of that same form, the idea being to try to find all the different species

220 of micro-organisms in that particular water. When a colony was seen to be different from the others, it was picked out and picked up and thrown on agar agar. If the culture proved to be a pure one, then it was shown in a variety of media to detect it, to ascertain its cultural characteristics.

The results were recorded on a chart that was original with our laboratory. Then those charts, 300 of them, some 30 different varieties of media, were used.

Experiments in this period were carried on in the same manner and according to the same rules laid down for the first period.

222 Result of examination above Bear Trap Dam drainage

canal, Lockport, Illinois, beginning September 26, as follows: (See table and Rec. 222.)

224 Illinois & Michigan canal, 9th street bridge, Lockport, Illinois. I took some samples from this canal to see what were the numbers in that also, because the Chicago sewage is being dumped into that from the south fork of the Chicago river. This is not the Chicago Drainage canal.

Results are as follows: (See table and Rec. 224.)

225 Quantitative determination of bacteria per cubic centimeter and the detection of the bacillus coli communis in the Drainage canal, just below Rubey street, Joliet—it is really the Des Plaines river. (See table and Rec. 225.)

227 Des Plaines river, Brandon's bridge, below Joliet, beginning September 26, as follows: (See table and Rec. 227.)

228 Des Plaines river two miles above the conjunction, with the effluence of the Chicago Drainage Canal. (See table and Rec. 229.)

230 Drainage canal and Des Plaines river at 9th street bridge, Lockport. (See table and Rec. 230.)

230 Drainage canal, 9th street bridge, Lockport. (See table and Rec. 230.)

231 Coli communis was found in 73 per cent of the samples collected daily at McDonough street, Joliet. That was in the second period we have just mentioned. That was given day before yesterday.

At Rubey street, 83% of the samples. That is the Des Plaines river at Joliet and at Brandon's bridge in 79% of the samples examined.

232 The next examination made, the laboratory was established at Peoria in the Y. M. C. A. building, and a few samples were collected at La Salle, in the Illinois river, and samples taken daily from the river at Peoria. These examinations were made immediately and they came to the laboratory immediately and were plated. That was at Peoria, below Peoria, at Pekin, and at Kingston, and further down, Beardstown,

samples were collected and sent back to the Peoria laboratory encased in ice.

At Grafton they were plated and examined right there.

233 The coli bacillus was found in October, 1901, in 87.1 and in November 79.1 per cent above Peoria at Shady Beach.

Quite a number of rivers enter into the Illinois river between Joliet and Peoria. The distance between Joliet and Peoria on the Illinois river is 120 miles. We have the Du Page, forming with or joining the Des Plaines river to form and join the Kankakee. The Fox comes in from the north, and the Vermilion from the south. I have viewed all these rivers but the DuPage. From Mr. Harmon and Mr. Cooley's figures I

234 find during the low water stages of October, 1889, the Des Plaines flowed per cubic feet per second, 13.21; the DuPage 32.77; the Kankakee, 509.24; the Fox, 329.95. He has the Vermilion marked here, 4, which is wrong because the Vermilion is a very much larger river than the Des Plaines.

At this particular time last year when this examination was going on, the water was particularly stagnant and very little water flowing out of it. That is out of the canal, the I. & M. canal, into the Illinois river.

235 The samples collected at La Salle were packed in ice, after being collected with the apparatus which is described, by a man employed there, collected above the point of discharge of the I. & M. canal into the Illinois river, so as not to have the effluence of the I. & M. canal mixed with this water. They were at once shipped to Peoria by express and examined there as soon as it arrived.

Water from Shady Beach, three miles above Peoria, was immediately carried to the laboratory in the Y. M. C. A. building at Peoria. Pekin sample was carried directly to the laboratory at Peoria.

Result of examination made at La Salle is as follows:

236 October 28, 1901, 7,500 coli present.

October 29, 16,500, absent.

November 15, 9,000.

Coli tests not made in the November samples at this point.

November 16, 38,000.

November 17, 19,500.

November 18, 13,500.

November 21, 68,500.

Three miles above Peoria, the results of the examination were as follows: (See table and Rec. 236.)

238 Pekin bridge, Pekin, Illinois. These samples were taken to Peoria on the same day. There is a street car that runs from Pekin to Peoria.

This is five miles below the Peoria sewage. It is above Pekin. It is above the railroad bridge, in the channel at Pekin, Illinois. (See table and Rec. 238-239.)

240 At Kingston, in the channel, three miles below Pekin. The sample was obtained and the test made at Peoria, traveling by train, a few minutes after being taken it was plated.

These samples were taken well below Kingston. The river was low during this time and a man drove down in a buggy as far as he could drive and collected his sample.

Results were as follows: (See table and Rec. 241.)

242 At Beardstown the sample was taken in the river above the town, right out in front of it. The samples were packed in ice and shipped to Peoria where they were examined in the bacterial laboratory by Dr. Rush. It would take but a short time to get the samples to Peoria, Beardstown being a couple of hours by train. Most always made the same day. I didn't superintend that part of it. But I saw it was working right. I had general charge of it traveling up and down from those points.

243 Result of that examination was as follows: (See table and Rec. 243.)

244 Next examination was made at Grafton. A laboratory was established in the Dempsey House, under the charge

of Mr. Leon G. Tedesche. Grafton is about 160 miles below Peoria.

245 In October, 1901, the percentage of coli bacillus found in the samples was 53.6—for both November and October, 53.6.

For October, 1901, the coli was found in 53.6% of the cases, and for November, 29.17% making an average of 45%.

These samples were taken and examined the same day. The laboratory was three miles from the place of taking on the Illinois.

They were taken in the middle of the stream, in the current, three feet below the surface, with this same apparatus I have testified about, and the same precautions were used and the same instruments were used.

246 The results were as follows: (See table and Rec. 246.)

247 Next was an examination of the waters of the Mississippi river two miles above Grafton, in the channel of the river, selected the same as the water selected in the Illinois above Grafton, with same apparatus and precautions.

The results of the examination were as follows: (See table and Rec. 248.)

249 In October, the percentage of instances in which the coli was found in the Mississippi river above Grafton was 33.33; for November, 62.50; total per cent 47, for two months. Those two rivers run very uniformly.

Samples were taken at Mississippi river, at Alton, one mile above Alton; Mississippi river at Hartford, Illinois; Missouri river, Ft. Bellefontaine; intake tower, Chain of Rocks; Illinois shore, Chain of Rocks; Missouri shore, Chain of Rocks; outlet screen chamber reservoir, Chain of Rocks; outlet

250 stream chamber; basin, Bissell's Point; tap in city chemist's office, 1141 Market st., tap at 5946 Garfield avenue.

First samples of water during this investigation were taken at the intake tower, beginning at St. Louis, September 14 and from that on until November 30. The samples from the Missouri river at Ft. Bellefontaine, Mississippi river at Hartford,

and Mississippi river at Alton, began October 4, October 5, October 6, rather, for Hartford, Illinois; and October 5, for Alton.

One mile above Alton, began on October 5, 1901, taken in the channel of the river, from a boat, taken ashore and brought back to St. Louis, carried there by the collector, the same day they were collected. Collected at ten o'clock and arrived at the laboratory about two, packed in ice, and plated at once.

The results were as follows: (See table and Rec. 251.)

252 Mississippi river at Hartford, Illinois, which is six or seven miles below Alton and one mile above the mouth of the Missouri river where it empties into the Mississippi. Hartford is 6 or 7 miles below Alton. These samples were sent to St. Louis. They reached the laboratory about 2 o'clock and plated immediately.

The result of the investigation was as follows: (See table and Rec. 253.)

255 Missouri river at Ft. Bellefontaine, six miles above the mouth of the Missouri where it empties in the Mississippi. Commenced taking samples October 4. Collector got the sample about 10 o'clock in the morning, reached the laboratory about two o'clock—between noon and two o'clock.

Results were as follows: (See table and Rec. 255.)

257 At the intake, Chain of Rocks, a cross session was taken by drawing a line across the river from shore to shore through the intake. The intake sample was taken in front of the intake tower anywhere from 100 to 300 feet in front of it, as the man rowed across the river. The first sample was taken 300 yards from the Missouri shore, and the third sample from the Illinois shore, 300 yards from the shore in the channel. The samples were taken ashore and plated immediately, and when the plates were hard were carried to the bacteri-

258 ological laboratory at 1141 Market st., and there incubated, and counted when ripe.

We will begin with the Missouri shore sample, 300 yards from the Missouri shore, just above a line drawn through the intake. You see it is impossible to get a sample below there

because it is rocky—a chain of rocks has been thrown out into the river to deflect the water away from the shore, so it would be shallow water below the chain of rocks; consequently the samples were taken above the Chain of Rocks, where the water was deep.

The results were as follows: (See table and Rec. 258.)

259 Missouri shore, Chain of Rocks, result was as follows: (See table and Rec. 259.)

260 Illinois shore, Chain of Rocks, the result was as follows: (See table and Rec. 261.)

263 At the intake the samples were taken at the intake tower from 100 to 300 feet above the tower in the river where the river was running fast. This was not taken from the intake tower itself. The intake tower is 1,500 feet from the shore, and the samples were taken in the channel in front of it. It is difficult to take a sample in a tower, because the water is pouring into it from all sides, and it is very difficult for a man to get down there.

The results were as follows: (See table and Rec. 263.)

265 Outlet screen chamber, Chain of Rocks is in the reservoir, after 70 hours rest in the reservoir. It compares about the same with a year ago, or a little bit better during that time. I think there wasn't so much bacteria in the water.

Samples were taken from the same place as in period number two. They were taken as soon as collected, to the house or pumping station here and plated immediately. The plates were put into a special apparatus designed by Mr. Damon and carried to the city chemist's office, 1141 Market st., and there incubated and counted afterwards.

Results were as follows: (See table and Rec. 266.)

268 Next samples were taken from the water in the settling basin at Bissell's Point—out of the settling outlet where the water was flowing out into the deep well that they have there. The results were as follows: (See table and Rec. 268.)

270 At the tap in the city chemist's office, 1141 Market st., the water was allowed to run five minutes before the sample was taken in a steriled flask and plated immediately. The results were as follows: (See table and Rec. 271.)

273 At the tap at 5946 Garfield ave., which was the residence of one of our bacteriologists, Mr. Snodgrass, the water was supplied from the Compton Hill reservoir stand pipe or from the high water service at Baden. It is about four miles directly across there, but you see it first come to the stand pipe and goes back to him, so it must have traveled six miles to the stand pipe and received its pressure there, and then was carried out to this district.

274 It traveled six miles to the stand pipe and about four miles from the stand pipe to his residence. That would be about ten miles.

The samples were brought immediately from the tap to the laboratory where it was plated. The results of that examiation were: (See table and Rec 274.)

275 The percentage of coli at each one of these places was, 1 mile above Alton, Ill., coli for October, 1901, 100%; November, 1901, 77%, making an average of 88.6 of samples collected.

276 Hartford, for October, 1901, 86.4%; November, 56%; average 70%. Hartford is seven miles below Alton.

Bellefontaine, October, 1901, 92.6; November, 1901, 80%; avreage of 86.2.

Missouri shore, Chain of Rocks, September, 76.9; October, 97%; November, 84.6; average for this period is 88.4.

Chain of Rocks, Illinois shore, percentage of coli for September, 1901, 76.9; October, 97%; November, 77%; average is 81.7.

Intake tower, Chain of Rocks, September, 1901, 76.9% October, 90%; November, 77%; average 80%.

Reservoir, Chain of Rocks, after sedimentation, September, 1901, 83.5%—there is something wrong in this typewritten copy

here and I will have to go over the results. I will go over those calculations tonight.

277 Outlet settling basins, Bissell's Point, September, 86.4; October, 94.04%; November, 93.8%; average 91.41%.

Tap at 1141 Market st., September, 85.7%; October, 97%; November, 80%; average 87.5%.

Average of bacteria at the Chain of Rocks intake for September, 14 days, is 2,686. This has no reference to the bacilli coli communis. That was at the outside of the intake in the river.

Outlet screen chamber settling basins, Chain of Rocks, after passing through the reservoir, 1,375 is the average, 14 days, after settling 70 hours, or the percentage removal of bacteria is 48.43%. The average for 14 days at Bissell's Point, outlet of the basins, the number of bacteria is 363, or the per centage of bacterial removal after passing through both reservoirs, is 86.05%. That means the loss of bacteria in the one reservoir and before they go out of another; that means 86.05 per cent have been removed to the outlet chamber of the second reservoir, from the intake. Now then, the removal to the

278 tap, 300—the number of bacteria removed per cubic centimeter, average 14 days, is 300. Percentage of removal is 88.83.

October average number of bacteria for the month is 20,500, at the intake in the river. The average number for October in the outlet screen chamber in the settling basin at the Chain of Rocks is 2,975. Percentage removal for this month is 85.6.

Bissell's Point, outlet of the basins, the number of bacteria averaged for the month, 1,137. Percentage removal, 90%.

Average number of bacteria for October at tap 1141 Market st., 843. Percentage removal 95.9%.

Average for month at 5946 Garfield ave., the tap, 412; per centage removal, 98.

November, total number of bacteria found at the intake, average 39,518.

Outlet screen chamber, Chain of Rocks settling basins, November, 7,600. Percentage removal, 81.5.

Bissell's Point, outlet settling basins, average number of bacteria per month, 2,545; percentage removal, 93.5.

Tap, 1141 Market st., average is 2,560; percentage removal 93.2.

5946 Garfield ave. tap, average number for month 2,880. This is more than the other place and I don't know how to account for it except that they were stirring things up in the pipes.

Percentage removal is 92.7, or I can give total percentage lost for those three months, which is 14 days in September all of October and all of November, at the outlet of the seven settling basins, and the outlet screen chamber, Chain of Rocks, 71.84 per cent.

279 Bissell's Point, outlet settling basins, 90%.

Tap, 1141 Market st., 92.64%.

Tap, Garfield ave., 95.3%.

Mississippi river, above Grafton, average number of bacteria per cubic centimeter for October, 1901, 717.

For November, 2,290:

Illinois river above Grafton, for October, 1,780; for November, 3,050.

MR. JEFFRIES: Now give us the result of the cultural and bacterial features of the bacteria found in the Illinois river, the Mississippi river, the Missouri river, Lake Michigan

280 and the Canal—that is the Chicago Drainage Canal during the second period from January to October, 1900.

A. Now this is a chart original with this laboratory, presenting the morphological, cultural and biochemical features of the micro-organisms found in the waters of Lake Michigan, the Chicago drainage canal, the Illinois river and the Mississippi river at the intake.

The bacteria here are classified into types according to the colors which they produce upon the media, or certain other

characteristics by which they can be confined to groups, distinctive groups, and the morphological, cultural and biochemical features which carry it through a variety of media.

We have on the fluorescens type first, the bacillus fluorescens incognitis. The first investigator was Wright—he first discovered it or found it in the water. It is a bacillus, motile, does not form spores. Under cultural feature now: in nutrient broth it produces a scum and the nutrient broth is made
281 turbid by it. In an agar tube it shows a wrinkled membrane.

Gelatine plate colony characteristic, not distinct.

Potato, a luxuriant and visible growth.

Fermentation tube does not produce gas.

Grows best at body temperature.

In gelatine it does not liquefy.

In milk it does not coagulate.

It does not liquefy blood serum.

It does not ferment.

It produces no gas.

Does not reduce nitrates.

Does not produce indol.

Again it does not coagulate milk.

Is chromo-genic on nutrient agar, and it produces fluorescens of the media.

Body temperature is a negative temperature, 98 3-5 or 36½ centigrade.

By developing I mean it grows best on our nutrient media, more vigorous in a definite period of time.

282 We have two words in bacteriology, aerobic and anaerobic. Aerobic bacteria grow best in the presence of oxygen. The an-aerobic bacteria grow best in its absence. Now there are classes of micro-organisms that grow under both conditions. They grow nearly as well under an-aerobic conditions as they do under aerobic conditions. Since they have this faculty of doing this thing they are called facultative an-aerobic

of facultative aerobic, depending upon which condition they grow best.

Indol is one of the products, one of the putrefied products of the result of destructive composition or the destructive action of bacteria upon organic matter.

307 Under the head of morphology we have here the question of the form of the micro-organisms—bacillus meaning a rod, and it is marked here either positive or negative. If it is bacillus positive, it is marked with a cross—positive; if in any other form than bacillus, it is marked negative, with a minus sign.

The next under morphology comes the diameter greater than 1M. "M" is for the Greek word Micron and micron is one

308 1-1000 of a millimeter, or 1-25,000 of an inch, so that a micro-organism here recorded will be larger or smaller than 1-25,000 of an inch, according to this chart.

Then comes motility. A micro-organism may be motile, that is, swim about, or it does not do so.

Under morphology comes the word spore which means that these micro-organisms contain within themselves bodies for the preservation of the species, so that the chart is marked positive and negative whether it be present or absent.

Under cultural features are the growth characteristics, with the certain nutritive media which will be named as we approach them.

Nutritive broth, that is nutritive broth as will be described, in test tubes, and into that the micro-organism is sown. Now it grows in that medium or it does not grow, and it grows in a certain way. If it grows in the medium making a cloudy condition in the medium that is recognized as turbidity. Then if the micro-organism grows out on the surface of the medium, forming a pellicle or membrane on it, it is called a scum and here so recorded. And if it is either one of these it is marked positive and if neither one, negative.

Under cultural features also comes nutrient agar-agar, of a definite percent in nutrient broth. This material is a solid medium and is slanted in the tube, and on the surface of that medium is sown the micro-organism in pure culture. Now the micro-organism grows and whether it grows with a dull growth, it is practically not transparent or translucent, and if the growth be wrinkled, it is so recorded here. If it does neither one, it is marked negative. If it grows dull or wrinkled, it is so marked.

The third feature is growth in gelatin plate. The micro-organism in pure culture is plated as described, generally in a petri dish, and this allowed to grow at 20 centigrade or about 60 degrees Fahrenheit. The growth that occurs here is called a colony which is a growing out of the micro-organisms into numbers sufficiently large to be seen either with the un-
309 aided eye or with the microscope. The colony has certain characteristics. These are marked as its appearance is characteristic or as it is not characteristic.
309 On potato, that is a potato cut into cylinders and then crosswise, so as to slant, it making a surface upon which growth can be easily made. Upon the steriled potato then is sown this micro-organism and the micro-organism grows either with visible growth or with invisible growth, and the growth is luxuriant or not so.

Under cultural features we have fermentation tubes. Now the question is whether a micro-organism in this fermentation tube, which is a "U" tube, grows in the closed arm or not. The heating of media in these fermentation tubes dries the air out of it, so that the medium in this closed arm is practically free from air, consequently a strictly aerobic or so called obligatory aerobic will not grow in that arm, while one that is facultative, or has the faculty of growing in the absence of any oxygen will grow.

Then we come to the biochemical features we have here recorded, growth at body temperature. Now the micro-organism

is sown upon agar-agar as a rule, and kept at the incubated temperature of the body, that is 98 3-5 degrees Fahrenheit, or 36½ degrees centigrade, or it is kept at 20 degrees centigrade, which is the ordinary temperature of about 60 degrees Fahrenheit.

Now, at which of these temperatures it grows best is here recorded, so that if it grows at body temperature—if it grows at that temperature best, it is marked positive. If marked negative, it does not grow that way best, while at that temperature. It does not mean that it does not grow at all, but that it does not grow so well as it does at the temperature below.

310 Affected by range of reaction, that was omitted in my testimony this morning, that means whether it grows in the presence of alkali, neutral or in the absence of an alkali or acid. We have first a medium alkaline to phenol phtalein 1.5%. Now in making up these tables I did not record that fact and that was omitted in my testimony this morning.

A second medium neutral to phenol phthalein, and a third acid, 1.5 per cent to phenol phthalein. Upon these three media the micro-organism is sown and the luxuriancy with which it grows indicates the reaction at which it best grows, alkaline, acid or neutral.

Under biochemical we have liquefaction, and we have first liquefaction of gelatin. Some micro-organisms have the faculty of digesting gelatin and liquefying it, and this is so recorded. It either liquefies or it does not liquefy. That is quite a cultural characteristic of these organisms, of most of these organisms.

The next feature is casein. The word "casein" is next used, which is the cheese of milk. Some micro-organisms have the faculty of growing in milk, precipitating the casein and reducing it to a liquid, others have not, so that is recorded.

The micro-organism is sown upon blood serum collected and sterilized in test tubes with the slanting surface, and kept at room temperature for 12 days, and if the micro-organism

liquefies that blood serum, it turns it to a fluid, it is so recorded. If it does not do that, it is so recorded, positive or negative.

Dextrose broth—that means a nutrient broth prepared as we will show, with one per cent of dextrose, sugar, added to it. Now that is put in a fermentation tube and the micro-organisms inoculated into it. If these micro-organisms break up the sugar so as to form a gas in the closed arm of the tube, we speak of that as gas production, and it is marked positive. If it does not produce gas it is marked negative.

In the reduction of nitrates, a nitrate broth is made up
311 and in it the micro-organism is sown, nitrate broth I should say, and if it reduces the nitrates to nitrites why that is so recorded, positive and negative.

Under the biochemical feature next is indol production. It is the result of destructive action of micro-organisms on organic matter. It produces a peculiar odor, a fetid odor, and whether it produces it or not, it is so recorded.

In milk sterilized in tubes, the micro-organism is sown. Now whether it coagulates the milk or not, it is so recorded, if it makes cheese. Then upon the nutrient agar-agar slanted in a tube, the micro-organism is grown, and whether it produces a color upon the medium or not, that is whether the bacterium itself has a color within its cell walls, that is spoken of as chromo-genesis, or pigment production. Fleurescent means that the toxines or whatever it may be which is produced by the micro-organism, colors the medium. The color does not remain within the micro-organism as impigment production, but it gives off a material which colors the medium itself. Then we have fleurescent coloration.

This chart is reproduced as Abstract Table No. 2 and will be found at end of this volume.

What I have testified to in reference to the bacterial qualities of this water in the forenoon and this afternoon is the result of practical experiments with the water under my supervision. Samples were collected from January 23 to October

11, 1900. Every micro-organism was separated out upon a gelatin plate which seemed to be different from the other micro-organism, and was first, after the agar-agar culture was obtained, sown in broth and its form and motility recorded from that. You see the bacterium undergoes three different transfers from the genatin plate to agar-agar, to get a good
312 growth of it, and then into broth so as to get as nearly as possibly constancy of form under these new conditions, and then here are recorded motility, size and form, and whether it contains spore or not and from this culture, if pure, all other cultural media was inoculated and recorded after a definite period of time. We were looking for constance of form and optimum reaction, and then recorded the results in books and then charted out as here shown.

In the sanitary examination of water there are several procedures, first the physical aspect of the water, that is, testing its temperature, its color, its turbidity, its sediment, its odor, hot and cold, that is the physical appearance. Then we have the chemical examination for the organic and inorganic constituents in the solution, and then the microscopical examination for the lower and higher forms of animal and vegetable life. Under the microscopical examination we have two kinds of examinations that will here be presented, first, the larger forms, what is known as the floating matter in the water, the animal and vegetable life, and known as plankton from planktos, the Greek meaning wandering. Then we have the so called bacteriological examination of the water which is an examination of the lower forms of vegetable life.

The history and method of microscopical examination of water is as follows: (Rec. 312.)

315 The samples of water for microscopical examination for Lake Michigan were collected first, July 23, from the four mile crib; next July 30, from the Carter Harrison crib, this is 1900. The third sample was collected August 9, ten miles out fro mthe Chicago shore. The fourth sample was

316 collected September 7th from the Lake View crib, and the fifth sample September 15th, from the two mile crib. From the four mile crib the result is as follows: (Rec. 316.)

Carter Harrison crib July 30. (Rec. 517.)

Samples collected ten miles from shore, August 9, the result was as follows: (Rec. 318.)

Sample September 7, from Lake View crib, was as follows: (Rec. 319.)

From two mile crib, September 15th, as follows: (Rec. 320.)

Result of microscopical examination of the discharge of the Chicago Drainage Canal before it passes over the Bear Trap Dam at Lockport, Illinois, on dates named: (Rec. 321.)

Des Plaines river at Joliet on dates named. (Rec. 331.)

These samples were all collected at the same place as the bacteriological samples for this 1900 period.

Microscopical examination of the Illinois river two miles above Peoria, Illinois, taken out in the channel three feet from the surface. (Rec. 334.)

Microscopic examination of the Illinois just above Grafton, Illinois. Three miles above Grafton, as follows: (Rec 339.)

Mississippi river two miles above Grafton, as follows: (Rec. 342.)

Mississippi river one mile above Alton. (Rec. 344.)

Hartford, Illinois. (Rec. 346.)

Intake tower, St. Louis water works. (Rec. 349.)

353 This chart is a graphic representation of the number of micro-organisms found in the Illinois river at Grafton. It is a weekly estimation taken from the daily numbers in samples obtained of numbers of bacteria in samples obtained at this point, beginning January 23, in the year 1900 to October 9th. (Rec. 353.)

Mississippi river at Grafton, two miles above Grafton. (Rec. 355.)

Mississippi river at Alton, Illinois. (Rec. 356.)

Mississippi river at Hartford, Illinois: (Rec. 358.)

Mississippi river at Ft. Bellefontaine: (Rec. 359.)

Missouri shore, Chain of Rocks: (Rec. 360.)

Missouri—Illinois shore, Chain of Rocks: (Rec. 361.)

Intake tower, Chain of Rocks. In the river about one hundred feet in front of the tower, up the river: (Rec. 362.)

Outlet chamber, reservoir, at Chain of Rocks: (Rec. 363.)

Tap, laboratory at old city hall, 11th and Chestnut sts: (Rec. 364.)

Map received in evidence and marked complainant's exhibit No. 1: (Rec. 364.)

365 (Referring to complainant's Exhibit 1.)

This chart shows the bacteria per cubic centimeter. The numbers recorded perpendicularly along the profile lines. The weekly averages have been obtained by adding the bacterial contents, obtained from samples collected daily, dividing by seven, which gives the weekly averages. These weekly averages are recorded, beginning January 23d, and ending October 9th, 1900. They are recorded for the Illinois river at Grafton, Illinois; the Mississippi river at Grafton, Illinois; the Mississippi river at Alton, one mile above the town; the Mississippi river at Hartford, seven miles below Alton; the Missouri river at Ft. Bellefontaine; the Missouri shore, Chain of Rocks; the

366 Illinois shore, Chain of Rocks; the tap, bacteriological laboratory old city hall, beginning May 8th, ending October 9th, 1900.

We make a comparative estimate beginning with the weekly averages at Grafton from January 23d to 30th, and compare it with each one of these elevations upon this chart for the individual stations where the samples were collected. The result is as follows: (See table "Abstract" and Rec. 366.)

376 This map indicates that the water of the Illinois comes into the Mississippi, so far as can be ascertained from the bacterial contents of the stream taken in the center of the river, we show a mixture both at Alton and at Hartford.

This is also a comparative estimate of the waters, of the cross section of the stream, Missouri shore, intake, Illinois shore, as you see here, show that quite often there is an intimate mixture at the intake of the waters of the three rivers, that is bacteriologically as is indicated on the two sides of the intake.

The waters of the Mississippi river and the Missouri river commingle at the intake, at times they do markedly, that is estimating the number of bacteria.

377 From memory I remember that the Illinois river was high from February 12, to 20, 1900. I know that the Mississippi river was covered with ice at the time and it was low, comparatively speaking. I know that the Missouri river was covered with ice at the time, and was comparatively low. In fact I know the period of the thaw in the whole Illinois river valley, the river was swept out, in February, 1900.

Beginning in the middle of February and running for a couple of months, all the rivers were high. They had the spring freshets then. That is when the bacteria flows in such enormous numbers, in all rivers.

378 The flushing of streams by the rains and floods increases the number of bacteria in the channels of the rivers.

In the Missouri river there are generally two periods of rise, there is the spring rise, which occurs as soon as the thaws and rains of spring begin, which may be in February or it may not begin until the latter part of March, depending on the weather. Then there is the flooding of the river with the thawing of the ice on the mountains, which generally is in June. The flood tides of the Mississippi are highest in spring. If there should be heavy rains in June there would also be a rise then.

I know that when the Mississippi and Missouri are high,

the Mississippi river above the mouth of the intake is high, the flood volume, I don't know at this time from memory.

It shows on this chart, (chart not identified) for the Illinois river, for the week beginning February 13, there
379 was a very high rise in the Illinois river which extends to the week beginning March 27.

During that period of time that bacteriological examination discloses to me as a bacteriologist that the water from the Illinois and Mississippi rivers was coming into the intake tower.

Here is the period of time at which the Illinois river was flushed. I call attention especially to the dates beginning in the week of February 13, and say extending to the week beginning February 20, during which time the numbers of bacteria in the Illinois river at Grafton were 257,600 and 221,800 respectively, for those two weeks.

The Mississippi river at that time was covered with ice, and the river fairly high. For the week beginning February 6, the number of bacteria in the Mississippi river at Grafton was 46,000, and the week ending February 13, the number of bacteria was 161,000. For the week February 20, at Grafton, Mississippi river, it was 105,500.

For comparison of weekly averages which witness claims shows an increase of bacteria in the Illinois as compared with the Mississippi and the commingling of those waters, see Rec. 379.

380 I am giving the bacteria per cubic centimeter for weekly averages, taking a definite period of time, and I show you by the river stages that the Illinois river was high at this particular time and contained enormous numbers of bacteria; that these other rivers were covered with ice, and were low in bacteria.

This chart shows that a mixture of the Illinois and Mississippi river at Hartford, and the mixture of the Mississippi river and the Illinois river and the Missouri river at the intake.

That is on the quantitative determination of the numbers of bacteria.

381 This chart, (Exhibit No. 2) is marked "Results showing mixture of the waters of the Mississippi and Missouri rivers at the Intake of the St. Louis water works, bacteria per cubic centimeter for the weekly estimations.

The bacteria per cubic centimeter on the Illinois shore is marked in black; the intake tower is marked red and the Missouri shore is marked blue. The figures on the left hand column indicate the bacteria per cubic centimeter.

The weekly estimates are here marked in black, upon the dates named, in the lower margin of the chart giving January 23, 1900, and extending through until October 2.

(The determination of whether the waters commingle at the Intake and what waters predominate is effected by taking the number of bacteria at the Missouri shore, the number at the Illinois shore and noting how the number at the Intake compare therewith.)

382 Complainant's Exhibit 3 is a chart of the weekly average of the result of quantitative determination of the number of bacteria in samples of water collected daily from the Mississippi river at Grafton, two miles above the town, together with the stages of the river at Missouri shore.

The red indicates the bacteria per cubic centimeter, and the blue represent the stages of the river.

On the left hand side we have the number of bacteria
383 per cubic centimeter, in five thousands, running from zero up to 250,000. Next to that we have a column bearing the stages of the river in feet running from zero to 25 feet.

My assistant, Mr. Johnson, made this chart, at my direction. This is also true of the chart marked complainant's Exhibit 2.

384 This shows that as a rule, running through here when the river is falling, the number of bacteria decreases

markedly; when the river is rising the number of bacteria run up to great heights.

This table shows that when a river steadies itself and is not washing the surface soil a great many bacteria disappear, not by settling but they are washed into the stream, it simply holds itself steadily, which shows here right straight along.

385 (Complainant's Exhibit 4.) This chart shows a weekly average of the results of quantitative determination of the number of bacteria in samples of water collected daily from the Mississippi river one mile above Alton, Illinois, together with the height of the Mississippi river at Alton, Illinois.

The chart was made from the data collected during the period January 23 to October 9, 1900, under my supervision. The determinations were made in the bacteriological laboratory at the old city hall, and medical department of the Washington University. These figures of stages of the river were obtained from the government meteorological survey. The bacteria per cubic centimeter is arranged perpendicularly, on the ieft hand margin of the page, beginning at zero and running to 250,000. The figures in relation to the bacteria per cubic centimeter are perpedicular and marked in red. Next to that, in blue, are the stages of the river running from zero to 25 feet.

386 When the river is high the number of bacteria is high. The greatest height of the river is reached on March 13, when it was 16 feet and about 4-10, and the number of bacteria recorded for that week is 312,000 per cubic centimeter.

388 (Complainant's Exhibit 5.) Chart same as above for Mississippi river at Hartford, Illinois.

389 Q. Now what, if anything does the bacteriological examination as disclosed by that chart, show with reference to the rise of the waters of the river and the fall of the waters, and the increase or the decrease in the number of bacteria per cubic centimeter, in the water bacteriologically examined?

A. With the rise of the river we find an increased number of bacteria in the water, and with the fall of the river, as a rule we find a decrease in the number of bacteria; so rising and falling then, as the river rises, beginning at its lowest period, it rises steadily until February 20, when the height of 7.9 feet is recorded; the number of bacteria at that time being 266,700. The river then drops to 5.6 feet in the week beginning February 27, when the number of bacteria dropped to 193,000 or 194,000, and then the river rises rapidly, in great volume, until the week of March 13, when 320,500 bacteria are recorded, as the weekly average; then with the fall of the river the bacteria drop very rapidly. The river falls in the week beginning April 27, to 2.2 feet about. The bacteria in that week fall to 60,000. The river seems to hold itself steadily here, falling until July 10, then there is a slight rise, the bacteria holding themselves steadily in the meanwhile, fluctuating between 7000 and about 2000.

390 (Complainant's Exhibit 6.) Same as above showing same condition at Ft. Bellefontaine, on the Missouri river.

393 (Complainant's Exhibit 7.) Chart showing same conditions at Chain of Rocks, Missouri shore.

395 The rise of rivers is caused by either thawage of snow and ice, upon the drainage area of the river, or rainfall upon it. This means water rushing towards the lowest part of the drainage area, sweeping the surface of the soil of its bacteria and carrying them with the water and debris into the river, and when the river falls and no longer has the bacteria swept into it from the surface washings, the river depends upon springs and sewers for water. That is, these particular rivers. Spring water is a good water and contains very few bacteria, consequently the numbers of bacteria during the falling or low stages of the river, are small.

397 (Complainant's Exhibit 8.) Chart representing same conditions at Illinois shore, Chain of Rocks.

400 (Complainant's Exhibit 9.) Same, Intake Tower, Chain of Rocks.

404 (Complainant's Exhibit 10.) Same chart for Illinois river three miles above Grafton, Illinois, without the height of the river recorded, the height of the water to be filled in later.

406 Prior to 1895 the Intake Tower of the St. Louis water works was located 3½ miles from Market st., measuring by the river, up the Mississippi, at a place called Bissell's Point. It was not near so well built as the present intake. It was built a short distance from the shore connecting with a bridge. It is an iron tower into which the water flower and was carried by low service pumps to reservoirs that were located at this point. When the river was very low they had a movable intake that ran down a tramway, carrying a flexible tube to follow the river out. The water was pumped directly from the river instead of running into the intake. There was a creek about 1,000 feet above the intake at Bissell's Point, known as Harlem Creek which discharged itself into the Mississippi river. This has a drainage area upon which there resided at that time probably 10,000 people. The sewage from these 10,000 people discharged upon this drainage area and into this creek, also the offal from a number of dairy stables that were built out and projected over this creek. All of this material during freshets was washed into the Mississippi river and at times flowed directly into this Intake at Bissel's Point.

407 This Intake was there 25 years ago. The city stopped pumping from the river at that point and began taking water from the Intake tower at Chain of Rocks in 1895.

408 I know that in 1892 the sewage ran into the Mississippi river about 100 feet above the intake at Bissell's Point, because I saw it doing it.

I know in '92 the attention of the Health Commissioner was called to this thing of the typhoid epidemic having resulted from this Harlem Creek discharging the sewage into the intake and a dam was thrown across Harlem Creek and pumps used so that the water that came into Harlem Creek was stopped and

pumped across, and discharged below the intake of the water workes, into the Mississippi river.

The typhoid epidemic following the discharge of this sewage occurred the latter part of August, 1892, and extended until February, 1893.

I made a personal investigation and found that standing on the bridge out on the Intake tower at Bissell's Point, the black dirty water from Harlem Creek could be seen running along in the yellow water of the Mississippi anl entering the Intake tower of the St. Louis water works. My atten-
410 tion was called to this in October, 1892. Dr. Francis, the Health Commissioner, and the St. Louis Medical Society made an examination. The facts were reported back to the Health Commissioner and he attempted to turn the course of Harlem Creek, over 500 yards back from the river. Pumps were established and the water pumped from this Harlem Creek to a point below the intake of the water works. That was practically the end of the typhoid fever there.

From the chief sanitary report of the Health Department for the fiscal year ending April 1, 1893, 3,624 cases of typhoid were reported to the health authorities by the officers of the city, with a total of 514 deaths.

The figures for the preceding year I obtain from the annual report of the Health Department of St. Louis. They are monthly and will be found on page 624 and 625. A great majority of the cases, 3,385 with 442 deaths, occurred during the months of September, October, November and December, 1892, and January, 1893.

412 I examined the Mississippi tap waters from the tap in the bacteriological laboratory and succeeded in separating out a micro-organism that resembled a stock culture very closely stock culture of bacillus typhoid. I thought it was the typhoid bacillus at the time and I still think so.

This was taken from the tap during this epidemic of typhoid, on November 8th. I did not make any bacteriological

examination of the waters of the creek as it was crude sewage and the numbers would be up into the hundreds of thousands, so I did not plate it.

413 I examined the conditions along the banks of the creek. All along from probably 400 yards from the mouth up to quite a distance along the crek are a number of dairies with their cow sheds projecting over this creek, and the manure is pitched out through the holes in the floor into this creek, great masses of it, lying there fermenting, and it is there still. I was over there the other day and saw it. A part of this drainage district extends into Bellefontaine cemetery and the other part is a rolling upland, and is inhabited and the sewage from all the people on this drainage area, probably 10,000, discharge into this creek, so that in dry weather the flow of this small creek has black fetid water flowing in it.

Prior to the breaking out of the epidemic there was typhoid on that drainage, of which there is a record in the health department.

414 In 1892 there was no other source of supply except that from Bissell's Point, with the exception of 7,000 wells scattered throughout the city. A mass of the wells were inspected and it was found that the typhoid fevers were uniformly distributed throughout the city and not around any particular well or wells—distributed independently of any well water.

In my investigation of the matter at that time I did not discover any cases among the families that used well water. The water was pumped directly from the river into the settling basins there, but the demand for water was so great in the city at that time that it rested but a short time; it was practically water delivered from the river to the consumer.

415 Describes method of examination of water at that time. Sound bacteria. It responded to all the tests and was declared by me to be typhoid bacilli.

417 This particular micro-organism lived in sterilized tap water, in an ice chest, right up against the ice, from 30

to 60 days. In non-steriled tap water in the sunlight they lived from 12 to 15 days, and in the gloom or dark of that ice chest, 24 to 30 days.

The chart here shown shows the number of cases of typhoid fever and the number of deaths in St. Louis from 1890 to 1900, graphically. I made that map. Besides that it graphically represents in groups the weekly averages of the river stages at St. Louis, the Mississippi river. The map goes further and shows another period which we will describe later. It was made from the official statistics of the St. Louis Health Department.

418 From 1890 to the year 1895 the water supply was taken from the Mississippi river at Bissell's Point. At the present time it is taken from the Intake tower, Chair of Rocks.

On the left hand margin of this map are written figures beginning with zero and running up to 200, written in black ink and they represent the cases and deaths, from typhoid fever. In the second column, or third from the left hand margin, the stages of the river, in feet, taken from the government figures and represent the stage of the river at the foot of Market

419 st., in St. Louis. The curved line in blue indicates the stage of the river. It begins in January, 1900, and the stage of the river was 6.1.

The black lines indicate the number of cases of typhoid fever reported to the Health Department and the red lines indicate the deaths from typhoid fever.

Witness reads from chart, beginning on page 49.

432 We find, in consultation with this map, that as a rule when the river is low the typhoid fevers were high, the number of cases and deaths. I mean the water low in the river.

On this chart is a separate chart running to December, 1900, upon which is shown the curves showing the weekly average of the stage of the Mississippi river at St. Louis; percentage of Mississippi water taken in; total solids flowing into the Intake, and number of typhoid fever cases for the year 1900.

I mean by total solids the residue remaining after evaporation. I made this map—it was under my direction. The data of the typhoid cases taken from the Health Department;
433 the total solids were taken from the figures of Dr. Wm. C. Teichmann, city chemist. The river stages were taken from the government reports.

434 Witness reads percentages shown on small map.

439 This map shows that typhoid was most prevalent in 1892. Prior to 1900 typhoid was most prevalent in the fall and winter months.

After a person receives the typhoid bacillus into his stomach the disease will develop itself from five to six days to three or four weeks.

440 Q. Now is there any relationship as shown by this map between the rise in the number of cases of typhoid fever and the rise in the percentage at the times you mention of the water in the Mississippi river at the Intake tower?

A. Yes, sir.

Q. Just explain what that is.

A. As I showed you already, on the 18th, 100% of the Mississippi river water, as it came into the Intake tower of the St. Louis water works—

Q. What do you mean when you say 100 per cent?

A. 100% of Mississippi river water. In other words the Mississippi river water only—not mixed with the Missouri river water, went into the Intake tower and on March 3d, there was an increase in the typhoid cases. That is February 8th and March 3d and 23 days later a rise in the typhoid death rate was noted and that increased until March 17th, gradually decreasing with the falling out of the Mississippi water here. The Mississippi water reached 12 per cent on the 17th of February,
441 and the typhoid fever cases on April 21st were recorded only 4. So that there was an increase of the typhoid cases from March 3d up to March 17th, then a gradual decrease to March 24 and from March 31st to April 7th, and as I say, reached the low number of four on the 21st.

From January 27 to February 10, the Mississippi river was falling, in 1900, and the Missouri river also at those dates was falling. I know that from February 6th, I think it is, to February 20th, the Illinois river was high.

The Mississippi and Missouri were frozen over from February 3d to February 20th. I think about the 20th they broke up.

Q. What effect on the oxidation by bacteria or organic matter, and animal and inorganic matter, in the water, does the freezing over of the river have?

A. The bacteria do not multiply very rapidly in cold water; they remain dormant.

Q. Well, the oxygen is shut out of the water by the freezing of the ice?

A. Yes, but there is enough oxygen in the water for the bacteria, if they could multiply in the temperature, but not so much as when the river is open. The organic matter in the water is not decomposed in so great a quantity.

Q. If there was organic animal matter in the water of the Mississippi river and in the Missouri at this time, its decomposition would be the result, if it was open and not frozen?

A. Yes, and the temperature higher, and the temperature not near freezing point.

442 Witness reads stages of Illinois river at Peoria from January 17 on.

444 These figures show that from the 23d day of January or from the 17th of January there was a steady rise in the Illinois river until the 29th of January, when eight feet were recorded, then there was a fall to 7.9 feet, and 7.8 feet on February 1st. It rose through February, March and April. 19.9 feet was reached on the 17th of March, and that is the highest.

Q. Do you know the date the Illinois river broke up?

A. Well, from what I understand, there was a thaw along the Illinois river beginning the 7th of February and it extended to April 12th. The river I see here begins to rise on the 8th, and

rises steadily from the 8th of February, and from the bacteriological record, and from personal recollection of samples collected at Peoria, at Joliet and Grafton, I know the condition of that water.

445 Trace the relationship there between the percentage of of the Mississippi river water as shown by this map and the increase or decrease of the typhoid fever rate.

A. We have traced that increase from March. That is for February, and the increase of typhoid fever that occurred in March in St. Louis, and no such thing has ever been known before in the history of this town; the Illinois river high, and the other two rivers covered with ice, and the Mississippi water coming into the intake in 100 per cent. Now as the rains began and the spring thaw began on the drainage area of all these rivers in the latter part of February and in March, there was high water for all these rivers, so the flood flowing into the Mississippi river was very great. From the 17th of February on, we find the highest stage of the Mississippi reached at this point was on March 17, 1900, and the highest stage also recorded for the Missouri at this period. This stage for the Mississippi was 22.4 feet and for the Missouri river 16.2 feet. Then the rivers fell until March 31, when again there was a rise. Then a gradual fall until the fall rise, which began on September 29th. Now at this time, according to the total solids, that is, beginning on March 3d, and reaching its acme on March 24th, we find that on March 24, 25, 26, 27 and 28th there was 100 per cent of the Mississippi river water going into the intake at St. Louis water works, Chain of Rocks. Then there was a fall to 62 per cent on the 29th of March; again a rise on the 31st to 100%; then a fall to 87% on the 1st of April and on the 2d of April to 50%. Then a rise on the 3rd of April to 62%, and a fall to 56% on the 5th. And on the 6th to 32%, and then, on April 7th to 1 %; then again it rapidly rose.

446 Q. Now what was the number of typhoid cases?

A. At flood volume of the river. It was very high at

this time and the number of typhoid cases rapidly diminished. All the rivers were very high, and the quantity of the pollution was very great. And the percentage of the Mississippi river water at the intake was high at one period, at the very high period.

Q. It wasn't high when all the rivers were at flood tide?

A. Yes, it was high once. That is the period I have just referred to from March 24th to 31st. It was 100%. I named the dates. It reached 100% twice in the spring and fall of 1900. So the quantity rises and falls; that is, the percentage of the Mississippi river water at the intake rises and falls until May 28th, when it is at its lowest; then it remained low, that is, rising and falling to a slight degree until July 29th, when it again rose, and the amount of Mississippi river water going into the intake reached 39 per cent. I can read farther on if you care to have me.

Q. Well, just trace the relationship there is in it between the typhoid rate and the percentage of the Mississippi river water.

A. The waters during this stage now, are—the Mississippi at the intake is falling when its percentage reaches 39; then the percentage fluctuates between the dates July 29th to August 7th, when it reaches 6 per cent. On August 31st the percentage again reaches 50 per cent. It falls on August 2nd to 2 per cent; then rises again to 28 per cent until the 5th of September. On the 7th of September it falls to 4 per cent, then it rapidly rises to the 12th, when it reaches 40 per cent.

447 The number of typhoid cases at that time was increasing, with the increase of the Mississippi river water at the intake at this low stage of the river.

The number at that particular point was forty cases. The percentage now fluctuates between 26 per cent on the 15th of September to 46 per cent on September 22nd; then there is a fall again, September 25th, to 34 per cent; then a steady rise until the percentage of 64 per cent is reached on October 4th.

Then it falls on October 6th to 27 per cent. rises on the 7th, October 7th, to 42 per cent; falls on October 9th to 24 per cent; on October 10th to 26 per cent, and the record ends there. When the flood volume of the river is very great the percentage of typhoid is very low.

Q. What water?

A. The percentage of the Mississippi river water at the intake, when the river is high, the typhoid is low. The typhoid fever rate increases with the increased percentage of Mississippi river water going into the intake.

Q. Take all this period here, the latter part or half of 1900, just give us the periods of time—just the dates, that is all, at which the typhoid was the greatest in the city of St. Louis—I just simply want the dates as shown by your map.

A. For the March term, for March 3rd, to March 31, extending into April 7th—March 3rd to April 7th, was one period, and from August 1st to December 15th.

448 I have made a calculation to determine what percentage of increase there was in March, 1900, of the typhoid rate in this city, or with that of the month preceding, February, 1900. It was greater for the period of March. For the period of February there is very little difference. For March there is an increase over March of the previous year. The number of cases of deaths from typhoid reported is as follows:

March, 1900, 40 cases.
March, 1899, 3 cases.
449 March, 1897, 3 cases.
March, 1896, 6 cases.
March, 1895, 6 cases.
March, 1894, 15 cases.
March, 1893, 14 cases.
March, 1892, 5 cases.
March, 1891, 6 cases.
March, 1890, 7 cases.

Above map offered in evidence as complainant's Exhibit No. 10.

When the flood volume of the river is very great the percentage of typhoid is very low—the percentage of the Mississippi river water at the intake and when the river is high, the typhoid is low. The typhoid fever rate increases with the increased percentage of the Mississippi river water going into the intake.

There is an increase of typhoid fever patients for March, 1900, over March 1899. It is greatly increased in March over February. The highest number of typhoid cases was recorded on the 17th of March, 1900, forty cases.

Above map offered in evidence as complainant's Exhibit No. 10.

449 This other map is for the third period, 1901, for the months of October and November. It shows the results of the daily determination of the number of bacteria in samples of water collected from Drainage Canal at Bear Trap Dam, Lockport, below Ruby street, Joliet, and Bran-
450 don's Bridge, Joliet. The bacteria per cubic centimeter are ranged along the left hand margin of the map, beginning with 200,000 and extending up to 5,000,000 bacteria per cubic centimeter. The bacteria at Bear Trap Dam, Lockport, are marked in black ink; at Ruby street, Joliet, in red; Brandon's Bridge, Joliet, in green. On the 4th space at the top of the map are the dates, beginning Sept. 26 and ending Nov. 29, the number of bacteria are recorded every third day—not every day.

The greatest number recorded at Bear Trap Dam recorded on this map is 7,200,000 on Nov. 23.

452 Now the water tumbles over the Bear Trap Dam and mixes it with the Des Plaines river and pollutes it somewhat, so that we see the pollution in this graphic representation.

Witness then reads from chart.

453 Now then we have the green line for Brandon's bridge. It shows a mixture of every stream and everything else that comes into the Des Plaines river—a mixture of the Drainage Canal with the Des Plaines river; the I. & M. canal with the Des Plaines river and the sewage of Joliet. The figures are as follows: (See Rec. 453.)

455 This map shows that the number of bacteria was the highest beginning the 17th of November—there was a lapse between the 10th and 17th—beginning on the 17th and up until the 23rd, when they reached the highest, but they are still high on the 25th, at all of these points.

The highest point was the Bear Trap dam.

Map offered in evidence as Complainant's Exhibit 11.

This chart you now show me is the result of daily quantitative determinations of the number of bacteria in samples of water collected at Peoria, Illinois, at Shady Beach, above the city; covering a period of time from Oct. 1st to Nov. 27th.

The lines and figures on this map, beginning on the left hand margin, show the number of bacteria per cubic centimeter, ranging from zero to 10,000, in black. The river stages in feet are printed in red and range from zero to 10 feet. At the top margin of the map are the dates from Oct. 1st to Nov. 30. The figures are as follows: (Rec. 456.)

457 This map shows there was a decided and rapid rise from November 13th to November 17th; then it dropped until Nov. 21, and then a rapid rise on Nov. 23 to 9,000, and then a drop for the 26th to 500. It seems to correspond with the rise and fall of bacteria at Bear Trap dam, Ruby street and Brandon's bridge at Joliet.

458 During this period the stage of the river remained remarkably even throughout, and when the bacteria was so high for the two periods in November, the water was a little bit lower than it had been for previous weeks. (Witness then reads the figures showing stage of the river for period referred to.)

459 You see the river fluctuated an inch or two only. The river remained stationary practically during this period from October 1st to November 29. In any ordinary river the bacteria would have remained practically stationary, but in the dates as given before you find a remarkable rise without any rise in the river.

This indicates that large numbers of bacteria put in above apparently came through to Peoria.

460 Q. Now above the Bear Trap dam, in the Des Plaines river, have you any analyses of that water?

A. Yes, that has already been sumbitted.

Q. Now you have investigated those analyses, have you?

A. Yes.

Q. What does it show—a larger or smaller number of bacteria above the Bear Trap dam than it does below?

A. Oh, a very small number, comparatively.

There is no other place than the Chicago canal at the Bear Trap dam from whence this large number could come into this river at this stage of the water.

I have the rain precipitation in that tributary of that river for that period. There was no precipitation practically in that area at that time.

Map introduced in evidence and marked Complainant's Exhibit 12.

Q. What is this map I show you?

A. This map is made up from results of the daily quantitative determination of the number of bacteria in samples of water collected from the Illinois river at Grafton, Illinois, from Oct. 1st to Nov. 27th, 1901. The distance from

461 Peoria to Grafton is 63 miles, and the mean fall of the river is thirteen feet.

Description of chart is same as previous exhibit.

Greatest number of bacteria per cubic centimeter were found 17th of Nov., 1901. There was slight rise of the stage of

the river at that date, but it was not as high as it had been at a previous period.

462 The river was five-tenths of a foot lower when the greatest number of bacteria was found.

Map offered in evidence as Complainant's Exhibit 13.

I was at Lausen, Switzerland, about 15 miles from Basle, as a sanitary and hygienic expert, in 1897. The town

463 is in the mountains—in the valley. Experiments were made by Dr. Haegler, after the typhoid epidemic of

464 1872, to discover the cause thereof. I have asked him what he knows of the history of this epidemic at this place, for the purpose of showing the manner in which it has been demonstrated that the typhoid bacillus will travel.

465 It went through the mountain, about a mile, and affected the spring at its base, and this mountain acted as a filter sufficiently good to keep out the starchy particles of flour thrown in a mile above, but allowed salt and typhoid bacilli to go through. This spring is enclosed; the spring is in an enclosed space, not open at all.

Never been to Plymouth, Pa., but am acquainted with the literature on the subject and the report made by the Pennsylvania State Board of Health, as to the typhoid fever epidemic that occurred there in 1885, due to the discharges of a

466 typhoid fever patient thrown upon the bank of the reservord that was the source of the water supply of this town. The town had a population of 8,000 and there were 1,104 cases.

Am acquainted with the investigations made—that is the reports of the State Board of Health of Massachusetts and of Dr. Sedgwick's writings of his investigation at Lowell, Lawrence and Newburyport on the Merrimac river, Mass., in 1891-2-3.

Objection by Attorney General Hamlin.

467 The epidemic at these places was due, at least ascribed ot the dejecta from typhoid fever patients getting into

the water supply and being taken and being dr[illegible] by these people. The town got its water from the Merrimac river.

I think Dr. Sedgwick carried out some experiments to determine the question as to whether or not it was in the Merrimac river, (the bacilli), but I am not sure about that.

Typhoid fever is more prevalent in the fall and early winter, as a rule. The faster water flows the further it will carry bacteria. In waters that flow very slowly, or are stagnant, or still, the bacteria are precipitated into the silt or slush at the bottom of the river. The speed of the river or the volume of the water does not destroy typhoid bacilli.

468 There is a difference in the conditions surrounding the typhoid bacillus in sterilized water in a bottle and the ordinary tap water in the city. Water that has been sterilized by heat contains the inorganic matter of the water, but the bacteria have been destroyed in it. It still has food for bacteria and it has no other bacteria. Now the typhoid bacilli put into that water have no other form organic leife to contend with and the bacteria will live a great deal longer in sterilized water of a district than they do in the living water of that district, in a bottle. They live sixty days.

469 Witness reads from table showing longevity of bacteria at various points along the various rivers, in sterilized waters. Witness then explains manner of collecting and preparing water in which to determine the length of life of typhoid bacillus, and reads on page 722 the weather conditions on each day.

473 Explains the manufacture of the media in which the typhoid cultures were made.

474 The typhoid cultures used in these experiments were: 1, from Dr. Westbrook, of the University of Minnesota, said to have been found by him in the waters of the Mississippi

475 at Minneapolis; No. 2, from a spleen sent in by Dr. W. C. G. Kirschner, from a patient dead of typhoid fever at the city hospital, and plated.

Water was taken from various points set out in the table and innoculated with the typhoid bacillus and they lived under conditions and for the length of time specified in the table, from which witness quoted on page 475.

479 The chances for life of a typhoid bacilli in running river water would be greater than if confined in a flask.

I don't see that the food supply cuts any figure in these experiments. I find that in sterilized, distilled water, micro organisms live for a long time. There is no assertion here made that the typhus bacillus lives and multiplies in the water. It simply lies dormant until its life history is over, unless in the meanwhile it reaches a favorable condition.

The death of the typhoid bacillus in water in a bottle is due to toxins produced by bacteriological conditions that exist there. In running water it lives out its period and dies after a time. Its period of longevity is not definitely known

480 in running water. The distance they would be carried, according to what men know of the longevity now, would depend entirely on the rapidity of the flow of the stream.

In the floodtide of the Illinois and Mississippi rivers, if typhoid bacilli came down from the Chicago river and emptied it in the Illinois river, they would come into the intake tower much more rapidly than they would if the waters were low.

I do not know from my own knewledge anything about how long it takes water to come from the dam at Lockport or from the canal there in Chicago, the Chicago river, down to the city of St. Louis.

481 BENEZETTE WILLIAMS, a witness called in behalf of the complainant, on direct examination by Attorney General Crow, testified as follows:

My occupation is civil engineer and consulting engineer, and I reside in Chicago. Have lived there 30 years. Have been following my profession for 32 years.

I am very familiar with the geography and location of the city of Chicago.

Chicago lies very low. With minor exceptions, elevations of the ground within the city is over the lake level to a height of 25 feet, and a very large portion of the city lying but a few feet above the lake level, both the old and central portion of the city and other portions, so that the process has been in the settled parts of the city, to raise the grades in order to get the depth to cover their sewers, and to get sufficiently out of the mire, you might say.

In other portions of the city they are overcoming that difficulty now by building sewer districts; building the sewers in districts and pumping the sewerage. They build sewers below the lake level and pump a flow to the lake level or to a point of discharge.

482 The soil on which the city is built is reasonably firm.

The greater portion of the city of Chicago is clay soil, overlaid, of course, with prairie soil originally, which is a soft loamy soil, free of stone and gravel. You find stone in the underlying clay. It has a glacial portion. Clay has what we term a glacial portion, and it is more or less filled with stone; that is sometimes cobble stone size and a gravel material to a greater or less extent. In some places you will find this clay quite pure with very little of that with it. In other places you will find almost a complete mass of boulders cemented together with clay; then another portion of the city lying directly along the lake at a certain depth consists of this same clay, but it is overlaid with a sand ridge formed by the flowing up of the lake and the washing and blowing of the same into the ridges. That is close to the lake, however.

But a small proportion of the surface of the city limits is on the lake level, but there are a great many square miles that are so low that you have to pump in order to get drainage. The land is flat, apparently, in its natural condition. It would seem like a dead level with the few exceptions of these sand ridges.

483 The greater portion of it would be about 12 and 14 feet above the low water of the lake, what you call Chicago datum.

The Chicago river and in fact all of the rivers that empty into the lake along the southern and western portions of Lake Michigan, you may say, have been formed as the lake shore—as the water receded, and the lake shore was built up so that they have been formed, so that they run parallel with the lake. They have been shut out from the lake as the waters receded by ridges of sand or drift, or something that has come in and left them running parallel with the lake. That is a peculiarity of that portion of Lake Michigan.

The Chicago river is short, originally not over a mile long from the lake back to the confluence of the two forks; one leading from the south and one from the north; the southern fork called the south branch and the northern fork called the north branch. The northern branch really drains the most territory and from a district of higher elevation somewhat as its source, which is in the State of Wisconsin. The south branch at a distance of about 5 miles from the lake, as it originally existed, has two branches, one known as the west fork, and the other as the south fork. The south fork draining a very limited territory, wasn't much, you could hardly call it a stream except in floods. The west fork only drained a small territory also, except as the flood waters of the Des Plaines river at a distance of about 9 or 10 miles from the lake would break over and come down
484 the west fork of the river; then that would become a large stream.

The Des Plaines river is another stream running parallel with the lake, but it is more remote from the lake.

The upper Des Plaines river heads in Wisconsin and flows southward until it comes to South Chicago, and about ten miles distant from the lake, when it turns southwest and joins the Kankakee, below Joliet, forming the Illinois river.

There is a divide between the Des Plaines and the south

branch of the Chicago river. That is the Des Plaines never flows into the Chicago river except at one point where it turns southwest to the Illinois river. It has always within recent geological times, at high stages, flowed both ways. It would divide, one portion going to the southwest, the other portion going to the east and through the Chicago river to the lake.

The distance to the extremity of the west fork of the Chicago river, of the south branch of the Chicago river, was only a very few miles, and really, within thirty years you may say it has been practically connected with the Des Plaines river. They built out there a ditch—the land owners did, and absolutely tapped the Des Plaines river and drew it to Chicago, even at low water, until the city went and built a dam and shut that off and restored the natural condition.

485 That is outside of the city limits and the distance from the present city limits is about 3 1-2 miles.

The north branch takes its origin at a distance of about 20 or 25 miles.

In the ordinary stage it is not a large river and in extremely dry weather it disappears practically. We have had floods there that discharged about 210 feet a minute—cubic feet in the north branch.

The mouth is a harbor now—it has been dredged and docked. The stream has been widened and deepened, by dredging.

486 Where it has been dredged it varies from a rapid current in high stages to no perceptible current at all. In ordinary times it is modified by some artificial work that has been done by the city, pumping works connected with it. The pumping works are at Fullerton avenue. There is a conduit extending from the lake to the north branch on Fullerton avenue, twelve feet in diameter, and a pumping works connected therewith. The works are at the river, but the conduit is below the lake so that it acts the same as if it was at the lake. It merely takes the water from the conduit and throws it into the river.

487 The capacity of the pumps when at its usual working capacity, is 15,000 cubic feet a minute. That was built about 1879. The conduit strikes the lake on the shore through Lincoln Park—it strikes the north shore of the city. It is adjacent to a densely populated portion of the city and extends directly west from the lake to the river 12,000 feet.

That conduit is in operation with the pumping works now at intervals, sometimes it is not working. The effect of that is to flush the river out to a greater or less extent, depending upon the amount of water put in. When flushed out it emptied at the confluence of the south and west branch of the river and from thence into Lake Michigan except as it went down the south branch due to a change of the regimen of the river.

488 For thirty years, there has been a flow through the south branch, southwest to the Illinois and Michigan canal.

The north branch carries the most water in its natural stage, except as I say in the Des Plaines river flood. As far as the size goes, in the rivers, as they stand today, perhaps there isn't much difference; they have been docked and dredged to the same depth and width.

From the confluence of the south branch and the north branch of the river to the exit in Lake Michigan, as it exists today, with the piers that have been extended out into the lake and caused a channel, is, I think about 7,400 feet. It is exactly 7,113 feet.

489 I can not say exactly how far the present opening has been extended out into the lake by artificial means. Nearly half of that distance is an extension from the original. There has been a filling in of the lake front at the mouth of the Chicago river with soil, debris, etc.

The mouth of the Chicago river was at one time, nearly half a mile south of where it is now. It turned south. It didn't change the river where it was naturally, you may say, from Rush street to the confluence of the forks, and at that point it turned south and entered the lake nearly half a mile south of where it is now. There was a bar existing there at what is now the outlet. They cut through that and have filled that old channel of the river—south of the river, what was the old channel of

the river, and they have been filling continuously more or less, and are today, out into the lake. I think the north branch is dredged and docked about four miles from the conjunction of the main river, but it is being dredged up as far as Lawrence avenue, about six miles above the confluence of the two branches of the Chicago river.

As far as it is dredged and docked at the present time it is opened for shipping and used for that purpose. The
490 depth is very near fifteen feet. Sixteen feet has been about teh deepest they have dredged up to within a few years.

The City of Chicago has been building a conduit at Lawrence avenue for several years, but there has been difficulty with the contractor and it is now tied up. It is 16 feet circular inside and will connect with the lake and extend across to the north branch of the river similar to the manner of the Fullerton avenue conduit and is in the northern portion of the city of Chicago.

That conduit is to take away by means of a system of intercepting sewers the sewage that now discharges into the lake along the north shore over to the north branch of the Chicago river, and it is also to take the supply of water from the lake to the north branch, with the view of emptying that sewage into it by means of the pumping station into the north branch of
491 the Chicago river which now goes into Lake Michigan.

The west fork of the south branch of the river has its origin very near to Ashland avenue and 31st street—or Ashland avenue and 26th street, in the limits of Chicago. It flows only one way; to the east, slightly to the north and flows in that direction now.

The volume of water is less in that than in the north branch, for ordinary times, but more at other times. That is there have been especially in the past before there were any changes in the conditions of the river, flood waters of the Des Plaines which have overflowed into that river, and swelled that river to a greater volume than the north branch.

Aside from any artificial interference the west fork carries

more water than the north fork at high floods of the Des Plaines. Where the Des Plaines overflows, breaks over and connects with it. That happens now but to a somewhat reduced extent. A flood must now be higher than in the past in order to furnish the supply to the north branch, but in very high floods it still furnishes a large amount of water there.

492 There is very little, almost no speed in the current—an almost imperceptible flow. It is dredged and docked for a considerable distance about the confluence of the south branch of the west fork, I should say two miles more or less. From the confluence of the two large branches of the south fork of the Chicago river to what was formerly the mouth of the Chicago river at Lake Michigan is about five miles.

The origin proper of the south fork of the south branch of the Chicago river is three miles south of its confluence with the south branch, and it was, you might say, merely gullies leading into a larger channel—it ran out into the prairies—it was practically no river at all, connected with what is known as the west fork. The drainage area of it was originally prairie with a flat surface and in the ordinary stage there was no water

493 in it—it was only a storm water drain.

At this time the south fork of the south branch is dredged and docked to the stock yards and that is one and one-half miles from the point of confluence of the west and south forks of the south branch of the Chicago river. It is dredged and docked for shipping. It is about 14 feet deep; lake vessels can pass in it there to the stock yards—they did do it. By the stock yards I mean the principal stock yards of the city of Chicago and the slaughter houses and packing plants.

All the live stock that goes to Chicago, except perhaps some that goes to Hammond, Indiana, goes in there.

There has been a conduit built from that we call the east arm of the south fork; that arm is merely a slip dredged

494 out for docks, for ships; the conduit leads to the lake and is 20 feet in diameter. It is to be used to carry sewage from the district, from Lake Michiagn on the south shore,

and south side, to the stock yards slip, and to take the sewage in from the lake to the stock yards. It is to be taken in for the purpose of supplying water to the river and flushing that south fork, that is, purifying it, putting in better and making it better in a sanitary way, and of furnishing water to the drainage canal. Pumps are being built there for a capacity of 120,000 cubic feet a minute. The main conduit is finished, they are cleaning it out now. The pumps have not been built. No one knows exactly when it is proposed to open that; probably in the course of a year.

495 The length of the conduit is 12,000 feet. There has been dredging going on in the channel of the south fork of the south branch of the river recently, especially up to te hmouth of this conduit, or the outlet of this conduit that is to be. Within the past year. They are certainly deepening it. They must have deepened it in the neighborhood of twenty feet. They are deepening at least at the outlet of this conduit, to the bottom of the conduit, which would be over twenty feet.

There is no flow in the south fork of the south branch except as comes from the sewage discharged into it and from the various sewers that connect with it.

496 The area of the sanitary district of Chicago is 185 square miles. After the legislation establishing the Sanitary District Board, I was chief engineer of the work from January, 1892 to some time in 1893, about a year and a half.

That area remains the same now as when established.

497 The sanitary district of Chicago is bounded on the north by Devon street, partly in and partly on the borders of the city limits. (Describes the boundaries of the district.)

498 Out of 186 square miles of area in the district, 141.8 square miles is within the city limits of the City of Chicago and 43.2 lies outside.

The Indiana state line runs north and south at right angles to the southern boundary of the sanitary district.

The eastern limit of the southern part of the City of Chi-

cago joins the State of Indiana; the western boundary of the State of Indiana.

500 Was city engineer of Chicago in 1878 or 1879.

501 Now what would you say as to whether or not the City of Chicago from its topographical and geographical location, is naturally adapted to the easy disposition of its sewage.

Objected to.

The building of the sewers was not a complicated problem in its original inception except in the matter of grades to give to the sewers. Finally a system of grades was established and used that was what might be called unprecedently low, that is the inclination was very slight—that wasn't the difficult thing only it was somewhat of a doubtful thing, that's all. That was caused by the level surface of the ground on which Chicago was built and the long distance you had to traverse with the sewers. In its natural condition water would flood it and stay flooded a good while, but you could and did adapt or fix the sewers to a natural slope to a certain extent. The surface was practically prairie soil and is not a good drainage, of course not for

502 a long distance run. You had frequent connections with the sewers to take off the surface water promptly. The precipitation of rain could not be drained fast enough by natural conditions.

In consequence of that frequent connections had to be made with the sewer to take care of the rain precipitation.

There is a difference in a city with reference to the amount of sewage matter produced according to the population and generally depending upon the manufacturing conditions. And also as to the general custom of connection of the sewers. An iron foundry and a machine shop or a planing mill wouldn't greatly affect the system of sewage, of the quality of sewage, but slaughter houses and stock yards and cattle pens are very liable to affect it materially and do.

In some cities that have a system of sewers the people will not all connect unless they are forced by some board of health. In the City of Chicago, I suppose, practically all connect with

the sewer as soon as one is built in the street. It is not a good place for cess-pools because of the impervious clay—that there would not be much percolation from a cess-pool. The sewage would accumulate and overflow. For that reason the sewer connection in the city of Chicago is very large and general. You might say practically that the only population in the city of Chicago that has not sewage connections in their houses, are districts that have not got main sewers built, and those are of minor importance.

504 As compared with my knowledge of the sewage systems of other cities, I think the proportion of organic matter flowing out through the sewers is greater in Chicago in proportion to the population than is usual, and only very extraordinary cases would have a greater amount than Chicago.

All the sewage that is laid below the level of Lake Michigan is in the southern district, about 60th street and east of State street. Compared to the whole city it is small, although it is large in itself. Some portions of it are quite densely populated and other portions even that are not sewered are densely populated. There are districts there where they haven't got any sewers at all, with 19,000 people in a district, in these flat, low districts.

In the territory where the sewer is laid below the level of the lake, that has to be pumped up to the water level to dispose of it.

Am familiar with the Illinois and Michigan canal. It
505 runs into the Chicago river and at 26th street at the place where the canal joins the south fork there is a pumping works. I think that canal was built in the '40's.

These pumps were built by Chicago for the purpose of creating a greater flow through the canal for the sanitary benefit of the Chicago river and were maintained by the city and operated until 1900 I think, when they were turned over to the sanitary district board. The sanitary district board has since turned them over to the Illinois and Michigan canal commissioners. They are now maintained for the purpose of keeping

up the level in that canal for navigation purposes.

506 The building of the sanitary canal was for the purpose of keeping the sewage in the city of Chicago out of the lake and polluting its water supply and for the purpose of improving the condition of the river and branches.

The outflow—the outflow of the sewers is mostly in the Chicago river and branches, although a portion goes into Lake Michigan and some into the Calumet river. The Calumet is in the southern part of the city, entering the lake about 92d street. It has its origin in Indiana. There are two branches and they both head in Indiana around the end of the lake and they flow generally westward, turning for a time, one of the

507 branches turning almost eastward, and a little south of eastward and joining the other branch, and then flowing northward and slightly eastward.

After striking the city of Chicago it has been dredged and docked, I think, to a width of 200 feet and eighteen or twenty feet in depth—I don't mean all the way—only its mouth. It is a pretty good sized stream. It has been dredged continuously for three miles at least and then it has been done in places so that the river has been navigable for boats of lighter draft clear up to Hammond, Indiana, a distance of nearly 20 miles from its mouth, following the windings.

507 The south branch of the Chicago river varies in width from 150 to 200 feet. At the bridges there is less than 100 feet up to the point of confluence of the west fork and the south fork. The sanitary district has been dredging and docking it and are preparing to widen and dock it so as to increase the flow and they have made it possible to increase the flow in places. But it don't necessarily mean that the flow has been increased though.

508 They are working to get a standard width or a minimum width of 200 feet and a depth of 26 feet to the central portion of the stream and 16 feet at the docks.

Based on the census made by the board of education of Chi-

cago in 1900, there is a population of 70,636 that drains into or is tributary to the Calumet river.

509 I have made a distribution of the population of the city of Chicago according to the points of watercourses to which it is tributary for the whole city, and I have represented that distribution and division of the city into districts on the accompanying map. The boundary of the city, except the lake shore is shown in blue, etc. (See Rec. 509.)

511 The board of education census is over 300,000 more than the Federal census, for the whole city.

512 I have confined my sewer districts within the city of Chicago—within the limits of Chicago. District No. 4 is outside of the sanitary district of Chicago and there is a small part of districts Nos. 11 and 10 that is outside of the sanitary district.

513 Now, outside of the city of Chicago, within the sanitary district is the town of Cicero, lying west, and having a population by the Federal census of 16,310. Also the villages of Lyons, Summit, part of Riverside, and a certain rural territory estimated in all, including Cicero, 18,145 in population in the sanitary district outside of Chicago. This makes the total population of the sanitary district based on the Federal census, 1,639,456. The Federal census of Chicago is 1,698,575.

515 ATTORNEY GENERAL HAMLIN: Now, at this point as you are proceeding along another branch, I move to exclude from the consideration of the Court, all the testimony introduced with relation to the Calumet district or district No. 4 as marked on this map, as that territory is not involved in this suit; this being an action against the Sanitary district and that territory lies outside of the district. I make that objection in behalf of the State of Illinois.

JUDGE SPRINGER: I make that objection in behalf of the Sanitary district.

ATTORNEY GENERAL CROW: I will offer this map in evidence.

ATTORNEY GENERAL HAMLIN: I object to it on the ground that it is not based, as far as the population is concerned, upon a proper basis; that it is based upon the school census and not on the Federal census.

516 Q. Now give me the population there, according to the school census, then according to your reduction to that corresponding with the same area as the Federal census in the sewer districts as you have divided them.

A. The population of Chicago by the school census of 1900 was 2,000,695. That has been distributed through the several sewer districts which I have mentioned, numbered 1 to 11 inclusive, and the population marked on the map, and they are as follows: consolidating certain districts in accordance with the source of water, or rather this point to which they drain. (Witness enumerates population of each district.) I find the population tributary to the main river and the south branch which is carried directly into the drainage canal by the flow from the lake, and is included in districts 1, 8 and 12, about

517 791,677. The population tributary to the lake on the south shore, and which will ultimately be discharged into the south fork through the 31st street conduit in district 2, 175,182. The population that is tributary to the south fork in district No. 5 is 282,655. That tributary to the west fork within the city limits in district 7, is 74,899. In addition to that I would add that a considerable portion of the town of Cicero has been sewered which lies within the sanitary district and that also drains into the west fork. The population tributary to the north branch of the Chicago river and that is included in districts 9 and 10, is 555,789. The population that is tributary to the lake on the north shore, district No. 11, is 28,878.

Now aside from those districts as described there is a district shown on the map there as No. 3 in the south part of the sanitary district with a population of 18,827; that has not yet a system of sewers otherwise, and while there is considerable population there, they have no sewage outlet. There is also dis-

trict No. 6 with a population of 9,152, which has no considerable amount of sewers—practically no drain at all.

District 4, which is the Calumet district lying in the city of Chicago south of the sanitary district, has a population of 70,636.

ATTORNEY GENERAL HAMLIN: That is objected to and I move to exclude it on the ground that it is not in the Sanitary district, and not relative to the issues in this case.

Summarizing a little further, I would say that there drains into the main river the south branch and the various forks which are tributary to those rivers, a total of 1,705,020 by the school census, and that there drains into the lake on the north shore and the south shore that are ultimately to go to the
518 Lawrence avenue conduit and the 39th street conduit now in the course of construction, 204,060. After these conduits are put into operation and the sewage intercepted and turned into the river that would have been distributed on the face of this population directly into the main river, the south branch and the drainage canal, 800,829:

Into the south fork, 476,664;

Into the west fork, 74,892;

Into the north branch, 584,664.

And the same quantity into the Calumet river before mentioned, making up the total population of the city in its manner of drainage.

Now to reduce them to the United States census, all those districts except No. 4, I would apply 16 per cent reduction. District 4 comprises wards or parts of wards that were found not to differ materially from the United States census.

Q. Now do you know approximately the amount of population of the Sanitary district that drains into the north branch of the Chicago river in say about up to the first of January, 1900?

A. Five per cent reduction would more than cover it and this would apply to the other branches of the river.

519 By the Federal census about 170,000 people—the sewage represented by 170,000 would drain into Lake Michigan.

520 The establishing of the pumping works at 26th street set the current of the river the other way and reversed the flow of the Chicago river.

520 The various branches of the Chicago river in the Sanitary district and city of Chicago were very badly polluted prior to January, 1900, with sewage and drainage from manufacturing establishments. The pumps at 26th street were inadequate to meet the purpose for which they were erected. I know that from a survey and examination of the whole question officially in 1886 and 1887. The water supply at that time was polluted by this sewage.

521 The city of Chicago from 1886 on up to January, 1900, was taking their water from the lake at various points of intake according to the dates and times. They took it from in front of the city from two to four miles out. I think none less than two miles. There are now five intakes and there were the same number in January, 1900. The most remote one is four miles out in the lake. They are as follows: (Rec. 52.) They are all connected. Of course the supply depends on the pumping works. There is a great number of pumping works in the city and of course from every pumping works it has a certain district that the supply from those works predominates. Some of them are located at the lake front and some of them many miles in the interior. There are no settling basins. The force is entirely supplied by pumps and there is no natural pressure or water tower. There is no system of filtration.

Describes the beginning and location of the drainage canal. (Rec. 524.) The bottom of the channel of the canal at Robey street is minus 24.46 feet, which means that it is below the datum to which all the levels are referred in the city of Chicago, which was low water mark of 1847 of the lake.

Taking a series of years, the lake fluctuates over a range of four or five feet, and over a range of several years taking the series of years up to a few years ago I found that the datum

was 1.9 feet lower than the mean level of the lake.

525 Now there comes the maximum rise of the lake which would go three or four feet above datum; and then there come times when it is a foot below datum. In every year there is a period of minimum level and a period of maximum level, the minimum coming almost invariably about January; the maximum some time in the summer, probably August. Then there are daily and hourly fluctuations due to the variations of the wind. Then there are seasonal fluctuations; there are a term of years often over ten years at a time that the lake will be continuously rising, these seasonal fluctuations, that is from August to January, still going on just the same, but the general trend is a rise—then there is the reverse. These are due, doubtless or probably ascribed to the rainfall.

525 Witness describes the canal. (Rec 525.)

529 Witness gives weekly averages of the flow of water in the canal after January 17, 1900. (Rec. 529.)

531 The pumps at the end of the Illinois and Michigan canal are on the south fork about a quarter of a mile south of the south branch of the Chicago river, which is the channel leading to the main drainage channel, and it takes its water from the south fork. The south fork is a very foul, black and malodorous stream and as fast as this water works out of the south fork towards the south branch it is taken in by the pumps going into the Illinois and Michigan canal, hence the preponderance of at least all that comes up to the capacity of the works from the south fork, goes into the Illinois and Michigan canal when they are in operation. That condition exists now. There is a current in the south fork of the south branch of the river but it is not perceptible to the eye. There is a flow due to the sewage and storm water that reaches that branch which flows northward towards the south branch.

532 The drainage from the stockyards all goes into the south fork or the slips of the south fork at the head of the south fork. Generally the pumps of the Illinois and Michigan canal are in operation. They operate those pumps now purely for the

purpose of navigation of the canal, to keep the level of it, astensibly at least that is what it is done for.

With the present flow of water through the Chicago river and the drainage canal the south fork of the Chicago river is yet stagnant water. At this time it is black, absolutely black. The lake water enters the river at its mouth.

533 The current in the north branch of the Chicago river is perceptible at times and at other times it is not. It is affected by storms and by the operation of the Fullerton avenue conduit—it is rather irregular—intermittent.

When the pumps at Fullerton avenue are at work they pump in 15,000 cubic feet a minute which would make a slow velocity in the canal. When they are not at work and when there is no storm water flowing, then it is stagnant.

The Illinois and Michigan canal, the only time I have seen it since the main drainage canal was open, it was apparently like it used to be before that channel was put in operation, very black and odorous and with a flow in the channel. There

534 was a flow prior to January, 1900.

When they are operating the pumps to their rated capacity there is a flow of about a foot in a second. That would be about two-thirds of a mile an hour. The Lawrence avenue system of intercepting sewers consists of an intercepting sewer beginning at the upper end of the sewer at the north line of Lincoln Park, and running northwardly to Lawrence avenue; and another one beginning at the city limits or near the city limits on the extreme north and running southward to Lawrence avenue, and making connection with Lawrence avenue, and on the line of Lawrence avenue to the river and the north branch of the river, those intercepting sewer systems, I would say are built; that is the sewers I have described are built and the Lawrence avenue conduit is built within a few hundred feet of Clark street. The remaining portion of it is not built.

That is to collect the sewage from all the sewers that enter into the lake on the north shore within the city limits, and conduct it through the north branch of the Chicago river by way of

Lawrence avenue—the sewage from the north end of Lincoln Park upward to the Lawrence avenue conduit and another one from the north line of the city to the Lawrence avenue
535 conduit. These sewers don't go clear through the north branch of the Chicago river, except the Lawrence avenue conduit. That sewage is to be pumped in the Chicago river. The Lawrence avenue conduit is built below the lake level.

The 39th street conduit is laid out in the same way. There is an intercepting sewer starting on the south at 73d street running north on Stony Island avenue and along the lake shore to 39th street and another one from 35th street south to 39th street. These two sewers will collect all the sewage now flowing into the lake on the south shore of the city, and deliver the sewage at 39th street. This system has been built from 39th street south to 60th street and is in process of construction. The conduit on 39th street is finished with the exception of cleaning up, and the water from the lake and the sewage from that district is to be put through the 39th street conduit with pumps. The 39th street sewer is all below the level of the lake and pumps located at the lake have been provided for lifting the sewage into the south fork of the river. The population that would contribute to the intercepting sewer on the north that is connected with the Lawrence avenue conduit would amount to 28,878 by the school census. There is no intercepting sewer connected with the Fullerton avenue conduit. From the school census the population of the area that is connected with the 39th street conduit is 178,182. By the Federal census would make 16 per cent reduction, or about 150,000.

In January, 1900, and at the present time, all the sewage from the district covered by this 39th street intercepting sewer system, ran into the lake.

537 If all the intercepting sewers now in process of completion, were finished, there would be none of the population of Chicago that would have the outflow of their sewage into Lake Michigan direct from the outlet of Chicago. Some of Chi-

cago goes into the Calumet, and goes indirectly into the lake, but nothing direct into the lake.

CROSS-EXAMINATION, By Attorney General Hamlin:

The Illinois and Michigan canal was constructed some time in the forties.

These pump works were established about 1879 or 1880. They have been in operation ever since at intervals most of the time. There have been intervals when they did not operate. They were in operation pretty much all the time from the time they commenced operation up to the time the drainage canal was put in operation. They were not shut down much.

538 After being put in operation they were under control of the city of Chicago. The Illinois and Michigan canal connects with the river that way.

From 1879 to January, 1900, the north branch of the Chicago river carried sewage, to the confluence with the main river, and with the south branch. That went sometimes to one place, sometimes another, sometimes in the lake and sometimes down the south branch. When the pumps were in operation it went the same, depending on the quantity of flood water reaching the river. The south fork of the south branch reached the stock yards district. The stock yards from 1879 to 1900 were about the same size, perhaps increasing some in the actual number of animals killed there.

The per centage of sewage discharged into the canal by the pumps was variable. In dry time when there was very little or no flood water reaching the Chicago river or its branches, and the pumps in operation to their capacity, which was then not far from 45,000 cubic feet a minute, there would be none of the sewage that went into the river reached the lake, only such sewers as had their direct outlet into the lake. It would ultimately go into the canal through the pumping works.

That condition existed about twenty years. The fall from Robey street to Lockport in the drainage canal—or as far

540 as Willow Springs, was at the rate of one in forty thousand, and from Willow Springs to the controlling works,

one in twenty thousand. The fall in feet from Robey street to the controlling works, I put it, I think at 5.55, that is the bottom of the canal.

The sewers that are to finally connect at Lawrence avenue and the other points I have mentioned are partly constructed but they are not in operation and the sewage that they will carry is now going directly into the lake. I think in 1900, February and March, they had the contracts let for the construction of these sewers. Based on the Federal census the population that drains in the lake would be not far from 150,000.

RE-DIRECT-EXAMINATION, By Attorney General Crow:

The controlling works consist of seven sluice gates that
541 move in slides and are operated by certain mechanical appliance. Each of those gates has an opening of thirty feet, clear opening. These gates were not all in use; they have not needed them; but they are there as a reserve when the flow becomes so great that they may need them. Then the early appliances relied upon for the main control now, is what is known as the Bear Trap dam, which is 160 feet long in its horizontal section and it has an oscillation vertically of seventeen
542 feet. The dam is made out of steel—a steel caisson, and the upper edge of it that points up-stream can be lowered or raised by the water. By letting the water in underneath the dam, it will be raised. By letting that water out into the tail race it will be lowered so that that dam can be oscillated just by operating valves, over a range of seevnteen feet.

I mean that if you put the dam down to the lowest point, it will be seventeen feet below what it would be if it was at its highest. It might not lower the water materially in front of it, it would be just pouring out as a mass over that dam, you know, a good many feet deep.

The town of Lockport is located off to the southeast of these works. The Illinois and Michigan canal lies partially between the drainage canal and the town. At this point the drainage canal is off from the Illinois and Michigan canal a considerable

distance. To go to the town you would have to cross the Illinois and Michigan canal.

543 These controlling works at the Bear Trap dam were constructed for the purpose of controlling the amount of water that passed out of the canal into the Des Plaines river, and the volume of water that can be discharged through these sluice gates will more than equal the amount of water taken in at the intake of the river at Chicago.

The necessity for these controlling works arises from the fact that sometimes they would want to shut it off entirely, possibly, and sometimse when you must limit the flow through the river, and as a matter of fact that is what they have been compelled to do all the time by the United States government. They have had to cut down the flow through the Chicago river in accordance with the standard set by the Secretary of War, and it is only by means of this controlling works, that they could do that. Without these controlling works it would simply run wild. That is it would simply flow all that the hydraulic conditions would allow until it would flow all the water that could go through the river and canal under the conditions of cross section and head and fall, and all of that. In other words it would do like a river itself; it would take its uniform flow and you would have no control over it. This was a measure of precaution for the purpose of controlling the outflow of water at all seasons.

544 DR. WALTER C. G. KIRCHNER, called on behalf of complainant, examined in chief by Attorney General Crow, testified as follows:

Am a physician and have been for two years. Am senior physician at the City Hospital. 28 years old. Assisted Dr. Amand Ravold in investigating Chicago river, Des Plaines river, the Drainage canal itself; the Illinois and Michigan canal; Illinois river, Missouri river and Mississippi river. Worked and assisted mainly in quantitative analyses of the water.

545 Began working with Dr. Amand Ravold about August 10, 1899. (This witness states the manner of taking samples of water, plating, etc.

555 EDWARD JAMES RAVOLD, called on behalf of complainant, examined in chief by Attorney General Crow and testified as follows:

Am brother of Dr. Ravold. (This witness testifies as to taking samples of water, the method, etc.)

568 DR. WALTER C. G. KIRCHNER, recalled, on further direct examination by Attorney General Crowe, testified as follows:

570 (This witness identifies the detail made of the bacteriological examination at various points, testified to by Dr. Ravold, and states them to be in accordance with the original figures made by him at the time of the examination.

582 (States method of taking samples and of conveying to laboratories.)

588 DR. AMAND NICHOLAS RAVOLD, resumed the stand for further direct examination by Attorney General Crow and testified as follows:

I heard and saw the comparisons made from the data Dr. Kirchener had and those you presented to him, and will say they are the same details for the corresponding period that I have heretofore read into the record in this case.

589 JAMES J. MOORE, on behalf of complainant; examined by Mr. Jeffries:

Worked under Dr. Teichman and Dr. Ravold, for the Health Department of St. Louis, in collecting samples of water. Describes method pursued.

593 FRANK J. BROW.., in behalf of complainant, examined by Mr. Jeffries:

Resides in St. Louis. Collected samples of water for Dr. Teichmann. Describes method pursued.

598 EUGENE BRUNK, in behalf of complainant; examined by Mr. Jeffries:

Live in St. Louis. Gathered samples for the Health De-

partment under direction of Dr. Teichmann. States method pursued.

605 JAMES GOLDEN, in behalf of complainant; examination by Mr. Jeffries:

Live in St. Louis. Am inspector in Sanitary Division of Health Department. Between months of May and July, 1900; worked under Dr. Teichmann, getting samples of water. States method pursued.

610 BENJAMIN FRANKLIN HART, in behalf of complainant; examined by Mr. Jeffries:

611 Live in St. Louis. Am water inspector for Water Department of St. Louis. From April to August, 1900, took samples of water for Dr. Teichmann. States method pursued.

616 C. V. MERSEREAU, in behalf of complainant; examination by Mr. Jeffries:

Live in St. Louis. Am civil engineer. Am assistant engineer in the Water Department of St. Louis.

617 From Jan. 22, 1900, to May of that year, I was working with men who were taking samples of water for the city chemist. States instructions given to the various collectors.

621 Explains method, apparatus, etc.

628 HENRY R. TAYLOR, in behalf of complainant; examination by Mr. Jeffries:

Live in St. Louis. Was janitor of the office of city chemist of St. Louis. (Explains method of preparing and sterilizing bottles used to collect samples of water.) I prepared all the bottles and shipped them.

633 FRANK J. BROWN, recalled in behalf of complainant; examined by Mr. Jeffries:

Identifies tags used on bottles shipped to city chemist's office from various points where the water was collected.

635 JACOB APEL, in behalf of complainant; examined by Mr. Jeffries:

Was collector of samples of water. Describes method pursued and places where water was taken.

DR. WILLIAM C. TEICHMANN, called on behalf of complainant, upon examination by Attorney General Crow, testified as follows:

640 My name is William C. Teichmann, and am forty-three years old. I reside at 3624 Shaw avenue, St. Louis. I am city chemist and have been since April, 1893.

641 I had charge of the chemical investigation of the waters of the Mississippi and the Missouri rivers and the Chicago Drainage canal and the Illinois and Des Plaines rivers which was begun along in 1899 and continued through 1899, 1900, 1901 and 1902.

The first period of investigation began on August 23, 1899, and continued until January 22, 1900.

642 I was ordered by the health commissioner of St. Louis, who is the superior official of my department, to take these samples.

Total number of samples collected during the first period was 142.

The points were as follows:

Mississippi river, Chain of Rocks, near Intake tower, 26 samples.

Mississippi river, Chain of Rocks, Missouri shore, 3 samples.

Mississippi river, Chain of Rocks, Illinois shore, 3 samples.

St. Louis water works, the uptake, 28 samples.

643 Mississippi river, Madison Landing, between Chain of Rocks and the mouth of the Missouri river, near the Missouri shore, 3 samples.

Mississippi river, Madison Landing, between Chain of Rocks and the mouth of the Missouri river, near the Illinois shore, 7 samples.

Mouth of Missouri river, 10 samples.

Mississippi river points, between Alton and the mouth of the Missouri river, 13 samples.

Mississippi river, near Clifton Terrace, between Alton and Portage, 6 samples.

Mississippi river at Elsah, near Piasa Bluffs, between Portage and Grafton, 5 samples.

Illinois river at points located, one, two, three and five miles above Grafton, 19 samples.

Mississippi river at points 1, 2, 3 and 5 miles above the mouth of the Illinois river, 19 samples, total 142 samples.

644 These samples were taken to the city chemist's office, St. Louis, and they were there analyzed by myself and my assistant, Mr. Thomas A. Buckland. From Aug. 23, 1899, for two months these samples were taken in demijohns, by holding in the hand under water.

Exhibit 16 is the character of bottle that was used in collecting the samples after two months.

647 Originally educated at Washington University, academic department. My education is chemical. I left the academic department of the Washington University and entered in the fall of 1875 the Polytechnic College of Brunswich, Germany. I studied chemistry at that college from 1875 to 1879. In the fall of 1879 I proceeded to Berlin and entered the University of Berlin, Germany. I studied there chemistry and a number of other corresponding branches, like history and literature, for general educational purposes from 1879 to 1881. In Berlin I studied principally under Prof. Ferdinand Tiemann, who is considered one of the leading authorities on water analysis, and the author of a well known standard work on water analysis. In 1881, in the summer, I left the University of Berlin and studied a half year's course in the University at Leipsic—I studied history. I then proceeded to the University of Munich in Germany and studied history from 1882 to 1885, and I graduated as a doctor of philosophy in chemistry and history in the year 1885, from the University of Munich, Germany

Under Prof. Tiemann, at the University of Berlin, I made a specialty of the study of the analysis of water. In 1885 I returned to this country and was principally occupied in literary pursuits until 1890. I then became private assistant to Prof. Charles O. Curtman, professor of chemistry in the Missouri Medical College at St. Louis. In 1891 I became assistant instructor of chemistry, as assistant to Prof. Curtman, in Missouri Medical College, which position I retained until 1895. In that position I assisted in quite a number of analyses of water. In 1893 was appointed city chemist of St. Louis. and have occupied that office since that time. Among the duties of the office, which are manifold, there is first of all, analytical work for the Health Department, which includes constant analysis of samples of well water and of cistern water. Some branches of it is continuous work.

Since this examination began, I have analyzed the water from the Chain of Rocks, not only for this litigation, but also for the water department, in order to give them a correct daily record of the water supplied to the city.

Prior to August, 1899, the analyses were made of a sporadic character. That is, they were not regular in intervals—it was only at times when the board of health just wanted to know how the city water supply was. I took samples then from the tapl and on one occasion, in 1893, in October, I took a number of samples from the mouth of the Illinois, and from various poins, about twenty-two samples, from various points between the mouth of the Illinois and the Chain of Rocks, but that was only one collection made, and I consider that analytical survey of a sporadic character, and I don't consider myself justified in drawing definite conclusions of the character of the water at that time from this sporadic series of collections.

The next period begins January 23d, and ends for the largest part of the collection of the samples on October 11th, 1900. During that period 3,492 samples were collected.

Witness then states points at which samples were col-

lected. Entire number of samples analyzed from Aug. 23, 1899, until Jan. 1, 1900, amounted to 4,000.

657 During the time above indicated, the samples were taken daily. From Oct. 12, this daily collection of samples outside of St. Louis ceased and we only collected weekly or semi-weekly after that period until November 30, 1900.

658 These bottles were tagged and the tags are here; there are about 8,400 of them.

659 The books containing the official register of the city chemist's office, of all samples of water beginning with 660 sample 148, until the present date, are stipulated to be in evidence but not to be printed. The record corresponds with the memorandum on the tags, and the register also states in every case that duplicate chemical sample was turned over to Prof. Keiser, and that the bacteriological sample collected at the same time by that collector had been turned over to the Bacteriologist.

There are five periods of investigation altogether.

661 This is the third investigation. The date particularly as far as the collection of samples at the Chain of Rocks is concerned, was from October 12, 1900, to September 30, 1901. During this period of collection analysis of samples was confined to such as were taken from the Mississippi river at the Chain of Rocks, daily, from the following points:

Illinois shore.

Missouri shore.

Intake tower.

Near Intake tower; one opposite Intake tower, from Illinois shore, and one from Missouri shore, Intake tower.

Also a sample was taken from the outlet chamber of the St. Louis water works, every day.

662 And from the top of the city chemist's office.

These samples were taken daily from Oct. 12, 1900, to September 30, 1901.

664 The next period was from Oct. 1, 1901, to Nov. 30, 1901. This was the most extensive period, or the period of the

most extensive investigation connected with this litigation. It was principally a daily collection of samples with the exception that at some points, cross-sections were taken and

665 for special scientific reasons connected with the investigation, samples at random had to be taken, but not consecutively every day, from day to day, but there was from a large number of points during this two months, daily samples collected.

665 The samples were taken from various points beginning with Bridgeport down to the intake. (See 1063-4-5.)

Tri-weekly samples were collected from Lake Michigan during this period.

666 Semi-weekly samples were taken from the south branch of the Chicago river at a point near the Chicago & Alton bridge; also at Wesley, Illinois, left, right and center section of the Illinois river. Wesley is three miles south of Peoria.

Four samples during this period at Omaha, above and below the city of Omaha.

Four samples from above and below the following cities, on the Missouri river:

Kansas City, Jefferson City, Herman, St. Charles.

Two samples were also collected from the following points:

Missouri river at St. Joseph, Mo.; Kaw river near Argentine, Kan.; from the Missouri at Wathena, Kan.

During this period occasional cross-sections of samples were taken at various points enumerated on page 666.

668 Next period extended properly from December 1, 1901, to July 1, 1902, and represents a daily collection of samples from the Mississippi river at the Intake tower and from the Missouri and Illinois shores; and also from the outlet chamber of the St. Louis waterworks and from the tap in the city chemist's office.

CROSS EXAMINATION

By Judge Springer.

671 The samples at Chain of Rocks, Missouri shore, were taken—supposed to be anywhere from 25, 50 or 75 yards. It is impossible to designate a particular point there on account of the current, but the general instruction was that the collector was to get a sample from the Missouri river current, which is generally supposed to hug the Missouri shore very closely, to get a sample of that current.

Q. Now what were your instructions with regard to the point on the opposite shore or the Illinois shore?

A. Exactly the same, only applied to the general supposition of a certain current hugging the Illinois shore there.

Q. How far was that point from the land, from the shore of the Illinois side?

A. Well, now, that varies very much according to the point taken at the shore, and it has to be left to the judgment of the collector largely.

672 My instructions in regard to that particular point was that they were to get water that was close to the Illinois shore, a certain current there with which the collector would very soon become familiar after entering upon his duties.

Q. Was there any distinction at that point between water which it was supposed by you or your collectors to come from the Mississippi river proper, or from the Illinois river in part—in other words, had the Illinois and Mississippi waters commingled at that point so that they could not be designated or separated from each other by the eye?

A. Well, we could only determine by the chemical analysis, that is, the results of the chemical analysis would demonstrate that.

675 CHARLES F. WERNER, called on behalf of plaintiff, examined by Attorney General Crow.

Collected water samples and testifies as to method pursued, etc.

684 DR. W. C. G. KIRCHENER, recalled. Upon examina-

tion by Attorney General Crow testified as to receiving samples at laboratory, etc.

686 LOUIS SAUER, examined by Mr. Jeffries. Collected samples of water. States method, etc.

689 DR. W. C. G. KIRCHENER, recalled, identifies tags on bottles.

691 ALBERT WINSCHELL, examined by Mr. Jeffries. Is a barber, collected samples of water. States places at which samples were collected, method of packing, etc.

697 FRED DIESELHORST, examined by Mr. Jeffries. Was collector of water samples. States how samples were collected, etc.

701 THOMAS A. BUCKLAND, examined by Mr. Jeffries. Am assistant city chemist. Identifies tags used on water samples. States the condition of the bottles when they came in; assisted in making examination of water under Dr. Teichmann.

706 EDWIN A. SLUDER, examined by Mr. Jeffries. Collected water samples at various places and states method used and places where samples were taken.

718 Stipulation and order of court of March 3, 1903, in regard to taking of testimony.

719 THEODORE G. RUFF, examined by Mr. Woerner. Collected samples of water. States method.

722 ED. BOCHERT, examined by Mr. Jeffries. Drove the wagon that conveyed samples from Chain of Rocks to city hall, etc.

726 ANTON KREH, examined by Mr. Jeffries. Collected samples of water. States places at which collections were made and method.

732 FRED B. WENZEL, examined by Mr. Jeffries. Collected water samples. States places at which collections were made and method pursued.

736 WILLIAM TOOHEY, examined by Mr. Jeffries. Collected samples of water. States places at which collections were made and method pursued.

DR. AMAND NICHOLAS RAVOLD, recalled and examined by Attorney General Crow:

740 I am acquainted with L. H. Taylor's report to the city board of health of Plymouth, Pa. I never was in Plymouth. Following as to information received from report, objected to by Attorney General Hamlin. It seems from the report the typhoid fever epidemic of 1885 in that town, was caused by a person being sick with typhoid fever in January and his dejecture, urine and feces were thrown out upon the side of the mountain, with the water reservoirs down below. Here in the ice and sun of this cold region, it remained frozen until early in March when it thawed and this water containing the feces ran down, into the reservoir, and when the superintendent of the reservoir found the lower reservoir low enough to permit him to pump, or rather to turn this water into the water supply of the town, then the pumping was stopped from the Susquehanna river and this water supplied, and within an incubation period of from two to three weeks, April 9th the first case of typhoid fever appearing, this epidemic occurred.

741 Water amounting to 5,000,000 gollans in reservoir was infected by the discharges of one person.

Have been to Hamburg, Germany. They have a water filter there for their city water supply. The water is pumped from the river Elbe, the Norder Elbe. First it is carried into

742 two very large sedimentation tanks. Here the water is allowed to settle from 24 to 36 hours and it is then carried across to a series of sand filters. They have forty to fifty inches of filtering surface. The water is admitted slowly from below until the sand in this whole mass of rock, etc., is saturated with water. The water is allowed to cover the surface of it. Then the filtered water is allowed to run in so as not to disturb the filter bed too much and anywhere from 30 to 50 inches of water are allowed to stand on top of the sand. The water that first passes through the filter is bacteriologically practically the same as that which runs into it—contains the same number of bacteria.

After a time the filter begins to filter. The bacteria has this little gelatinous capsule on its cell wall which permits it to adhere to a grain of sand or to one another and in this way a glue like mass was in the sand layer of the filtering tank, or as the Germans call it, a Smutzdecke is formed. This bacterial layer now catches all bacteria and solid particles that are in
743 the water as it passes through the filter and holds them tenaciously.

The water passes from these reservoirs into what is called a clear well at Hamburg. The clear well is covered. Every few hours a sample of this water is taken. This well is walled, with masonry. The water taken from this clear well, according to the German law, must not contain more than 100 bacteria per cubic centimeter. If it does the filter is not working properly and is put out of use. There are what is known as open filters, not covered as they are in Berlin. The filter basin is open. That number of bacteria is harmless.

744 I have here chart showing the course of the typhoid fever in Hamburg before and after the filtration of the municipal water supply. On the left hand side of this chart of figures ranging from 0 to 100. This represents deaths per 100,000 of population. Along the lower margin are written in figures in ink, the years from 1880 to 1898. Then I have columns here in black and the deaths per 100,000 can be read from the left hand side of the map and also from the figures written on top of the column.

From 1880 to 1893 in May, the average death rate was 39.7 per 100,000. From 1893 to 1898 the average death rate after this filtration is 9 per 100,000.

745 Said map marked Exhibit 21.

I received information through Dr. Seibert of New York, of the New York Medical Journal, that in 1901 the typhoid death rate in Hamburg was one death to 60,000 of population. So if marked on that map it would be a very small column showing the efficiency of filtration against water born diseases.

Have seen the water supply of London. They have the old-

est filters in the world, started to put them in in 1829 and are much similar to the Hamburg filter. I saw those at Lambeth and Hampstead.

746 The water is pumped from the Thames. There was a great decrease in typhoid death rate in London following the introduction of the filter system.

The water supply of Vienna is taken from the Springs in the Schneeberg mountains. They come 67 miles. When I was there they were intending to put in filters of the Wormse of Plague type.

748 The death rate from typhoid in Vienna is very low. In 1890 it was 9 deaths per 100,000 population.

Have been in Berlin and investigated their water supply from a sanitary standpoint. They have a filter water supply.

749 From 1843 to 1853 the typhoid death rate was 1 to every 900 inhabitants of the town. The first filter was put in in 1856. Now 1883 to 1893, before the bacteriologists had really taken hold of this subject of filtration, before we understood it, the typhoid death rate was 1 to 900. In the meanwhile Berlin had some shallow wells in which some of the water supply of the town was taken, but from 1892 on when the new works were put in with all water filtered, we find that in 1900 it is reported there was one typhoid case to over 50,000 in-

750 inhabitants. That is a remarkable reduction.

Have investigated the water supply of Paris, France. They have some filtered water there and water brought a long distance from springs in the mountains as high as 100 miles.

They also pump directly from the Seine. In some houses you will see two faucets. One faucet has a sign on it, "This is dangerous. Do not drink it." The other is the good water that has been filtered or that has been brought in from the mountains.

They have sand filters pretty much the same as the Hamburg and Vienna and Berlin filters.

751 I am familiar with the report of the man who made the investigations, Dr. Thorne, of the epidemic of Catterham

and Red Hill, England, in 1879. The water supply of Catterham and Red Hill was supplied by a water company which pumped their water from deep wells. Two of the wells were somewhat near together and it was decided to connect them with a tunnel or an adit, and they were working on a small tunnel for the purpose of connecting these two wells together.

One of the workmen worked from January 5th to 20th. He had diarrhoea all this time and on the 20th was so sick that he was taken to his bed and remained there. While he was at work his discharges were carried up in a bucket that carried up rock, and discharged on the surface of the soil. It was a liquid discharge and the leakage from these buckets affected the water supply. On January 19th the first case of typhoid occurred. All of the typhoid occurred in places where the water supply was had from this company. The inmates of the Insane asylum and the military forces stationed there, who received their water from an independent well, were not affected.

752 I am familiar with what is called the London Bond Street Pump Epidemic. The pump was sunk into the ground on Bond street and the water was taken by a number of people living in that neighborhood. It was said to be a good well and the water was sparkling and tasted very nicely. When this cholera epidemic was investigated by the authorities they found that close to it was a cess pool and also a sewer that carried the sewage from one or two houses near by it.

There was found to one side or near it, when this cistern or well was broken, a drain which was practically pervious, allowing the sewage to come through and also the cess pool which allowed the discharge to enter almost directly into this well. The case of cholera existed in the house that used this cess pool and the feces were carried directly from the cess pool into this water.

Witness reads from Hill's work on public water supplies, the deaths per 100,000 in foreign cities.

Witness then reads deaths per 100,000 in cities of the United States. The foreign cities have filtered water supply

while the United States has not and the difference in deaths is in favor of the European cities.

756 ARTHUR C. LOOLEY, examined by Mr. Woerner. My business is grocery clerk. Was employed to collect samples of water for Dr. Teichmann. Explains method pursued, etc.

759 DR. AMAND NICHOLAS RAVOLD, resumed the stand for further direct examination by Attorney General Crow. This is a chart prepared by me. It reads as follows: Chart showing cases and deaths from typhoid fever in St. Louis, Missouri, when water supply was taken from the Mississippi river at Bissell's Point, from January, 1890, to September 28, 1894, to December, 1902, when the water was taken from the river at the Chain of Rocks. Below that is written water from Bissell's Point, January, 1890, to September 28th, 1894, five years. Cases of typhoid fever 1,268. Below that is writ-

760 ten: Water from Chain of Rocks, 1895 to 1900, five years. Typhoid fever cases, 2,490; deaths from typhoid fever, 562.

Back of that is written, with an index pointing to the percentage decrease in typhoid fever death rate 125 per cent.

That is the difference between these two points. The reason for this decrease is that when the water was taken from Bissell's Point, Harlem Creek, which drained an area containing 10,000 inhabitants, discharged its contents into the intake of the St. Louis water supply.

761 Next is water at Chain of Rocks since the opening of the drainage canal, January 17, 1900, 3 years, 3,426 cases and 588 deaths.

Water at Chain of Rocks three years before opening of the drainage canal, for 1897, 1898 and 1899, 1,807 cases; 350 deaths.

Back of that is shown increase in typhoid death rate since opening of the canal, three years, 68 per cent.

From the statistics of the Board of Health of St. Louis this chart has been made to graphically illustrate these matters.

The Harlem creek epidemic occurred in 1892.

In 1890, there were 547 cases; deaths 277;

In 1891, cases 447; deaths 160;

1892, 3,624 cases; 488 deaths;

762 1893, cases 788; deaths 215;

1894, cases 816; deaths 178.

During 1893 and 1894 the Harlem creek still affected the conditions somewhat because in high water the pumps were not heavy enough to take all of the water that is discharged on that watershed, so it ran over the dam.

1897, 433 cases; 125 deaths;

1898, 426 cases; 95 deaths;

1899, 948 cases; 130 deaths.

764 In 1899 we have a remarkable number of cases. In November, 488 cases reported and 31 deaths; and in December, 116 cases and 20 deaths, which makes this great increase here.

The river was so low in 1899 that it was feared that the lowest gates in the intake tower would not be low enough to admit enough water for the pumps, so a coffer dam was built about the intake and men put at work breaking a hole through this tower and they got down pretty low and stirred up the mud in the bottom of the river.

The result would be, of course, part of it, to stir up any bacteria, any typhoid or pathogenic bacteria in the water there.

765 I have no data to assist me in drawing a conclusion that that was really the cause, although the cause for that particular flare in November has been ascribed to the work that was going on in October, in that tower.

I know that at that time there were dredges at work in the Illinois river below Kampsville.

766 In 1900 there were 1,213 cases, and 168 deaths;

1901, 1,101 cases, 198 deaths;

1902, 1,112 cases, 222 deaths.

Map offered in evidence as Exhibit No. 22.

767 Chicago has a population of 1,650,000 according to the United States census.

The proportion of population in the vicinity of Chicago, which also discharges its sewage into the drainage canal above Lockport, is roughly estimated at 350,000 people.

That makes approximately 2,000,000 people whose waste products are emptied in the drainage canal above Lockport.

768 There are about three ounces of solid excrementatious matter and 40 ounces of urine per capita per day. That is a low average. If each of those 2,000,000 people discharged three ounces a day the total results would be above 187 to 190 tons of solid matter, human offal.

769 Forty ounces a day would give 670,000 gallons of urine per 24 hours.

When I say sewage I mean the urine and feces and liquid matter flowing in a sewer.

The consumption of water by Chicago is 150 gallons per day per inhabitant, which would make the consumption reach 360,000,000 for the 2,000,000.

770 The dilution of sewage by waters flowing in drainage canal assuming that 300,000 cubic feet are discharged per minute is as one is to nine. The diluted sewage at Lockport does not approach in the slightest degree to the resemblance of a sanitary water.

767 The population of Chicago is given by the last U. S. Census as 1,650,000. Sewage from 350,000 people is also discharged in the canal above Lockport. This is outside of the Sanitary District. The waste products of these
768 2,000,000 people are emptied into the Drainage Canal above Lockport, 27 miles approximately from Chicago.

There are about 3 ounces of solid excrementatious matter and 40 ounces of urine discharged per capita per day. 2,000,000 people discharging 3 ounces per day would be about 187 to 190 tons of solid matter, and 40 ounces of urine a day would give 670,000 gallons of urine. That is per 24 hours.

769 The water consumption of Chicago is 150 gallons per

inhabitant per day, making something like 360,000,000 gallons per day for the whole population.

770 Based upon the assumption that the Drainage Canal was discharging 300,000 cubic feet of water per minute, we find the sewage of Chicago would be diluted as 1 to 9—that is one of sewage to nine of water.

It is readily seen by a perusal of the bacteriological resykts which have been submitted here, obtained from an analysis of samples collected daily at Lockport, that the diluted sewage at this point does not approach in the slightest degree to the resemblance of a sanitary water. The effect on fish of this water at the Bear Trap Dam was to kill them. In November 1900, 500 fish were observed passing over the dam in the space of ten minutes.

772 1900 census gives Peoria a population of 56,100.

Before canal was opened the minimum flow of the Illinois river at Peoria, according to Mr. Harmon's figures from his report to the Illinois State Board of Health, is 1,221 cubic feet. We figured it 1,200 cubic feet per second.

Q. Now assuming that the people in Peoria had an outfall of sewage equivalent to the same number of people in the city of Chicago, how many gallons per day per capita at Peoria would go into the water of the Illinois river?

ATTORNEY GENERAL HAMLIN—That is objected to on the ground that there is no allegation in the bill charging the discharge of sewage at Peoria, or any claim made growing out of any such discharge.

A. Assuming the same we would have 150 gallons per minute. Basing it on a flow of 1,200 cubic feet per minute and taking 56,100 people with a discharge of 150 gallons per head per day, that would give a dilution of 1 to 92 at the low river stage. That is the Peoria sewage. The distance from Peoria to Grafton is 160 miles.

773 With the 300,000 cubic feet per minute added by the

Drainage Canal, if that were added to the low river stage of the river, at Peoria, the dilution would be 1 to 413.

Q. If the Chicago canal water were free from sewage contamination and was emptying this Lake Michigan water in the pure state into the Illinois River at Peoria, at low stage of the Illinois river, would the pollution from Peoria, if the pollution in the sewage is in the proportion that you have stated heretofore, render unpotable the water of the Illinois river at its confluence with the Mississippi at Grafton, 160 miles below, from a bacteriological standpoint?

I mean fit for domestic purposes, drinking and cooking.

A. Well, it would reduce the danger to a minimum, that is just dilution alone, at Grafton.

JUDGE SPRINGER—I want to enter an objection to that question and answer from the fact that it does not illustrate any issue in this case, and from the further fact that there is a great deal more pollution from Peoria comes into the stream from Peoria, and the Illinois river.

774 One sixth of the sewage of persons in towns not sewered, rural districts, in proximity to rivers or the feeders there-

of, brooks and streams, eventually gets into the stream. I have a report of L. E. Cooley. (Said report is as follows):

| | Des Plaines River | Du Page River | Kankakee River | Fox River | Vermilion River | Mackinaw River | Spoon River | Sangamon River | Crooked Creek | Macoupin Creek | McKee's Creek | Illinois River, direct | Sanitary District of Chicago | Totals |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Flow per cubic feet per second | 13.21 | 32.77 | 509.24 | 329.95 | 4 | ..... | 87.78 | 372.30 | ..... | ..... | ..... | ..... | ..... | ..... |
| Urban population, census 1890 | 20,354 | 5,344 | 26,697 | 72,763 | 17,543 | 5,247 | 19,619 | 103,720 | 12,738 | 9,155 | ..... | 135,139 | 1,800,000 | 2,241,320 |
| Rural population | 43,247 | 10,890 | 140,441 | 80,880 | 43,257 | 30,106 | 56,428 | 177,638 | 44,289 | 32,296 | 8,823 | 184,877 | ..... | 864,183 |
| Total population | 75,601 | 16,234 | 170,138 | 162,652 | 60,800 | 35,353 | 76,047 | 281,358 | 57,028 | 41,453 | 8,823 | 320,016 | 1,800,000 | 3,105,503 |

776 Alton has a population of 15,000. It discharges its sewage into the Mississippi river. They have five main outlets, three of which empty into the Mississippi river, behind dikes, which quite effectually check that portion of the sewage from becoming mixed at once with the waters of the main channel of the river.

Hartford is on the Illinois shore, five or six miles below Alton, about one mile above the point where the Missouri river enters into the Mississippi river.

777 I have the average number of bacteria found in the waters of this river at these two points, Alton and Hartford.

MONTHLY AVERAGE RESULTS OF QUANTITATIVE ANALYSES OF MISSISSIPPI RIVER WATER ONE MILE ABOVE ALTON AND OPPOSITE HARTFORD RESPECTIVELY, TOGETHER WITH THE AVERAGE RESULTS OF THE TESTS FOR THE BACILLUS COLI COMMUNIS.

| | January, 1900. | February, 1900. | March, 1900. | April, 1900. | May, 1900. | June, 1900. | July, 1900. | August, 1900. | September, 1900. | October, 1900. | October, 1901. | November, 1901. |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Alton Bacteria | 118,800 | 192,500 | 192,300 | 20,400 | 10,300 | 8,200 | 7,700 | 2,400 | 2,600 | 2,100 | 1,137 | 1,566 |
| Percentage Bacillus Coli Communis | .14 | .17 | .51 | .39 | .54 | .60 | .52 | .88 | .90 | 100 | 100 | .77 |
| Hartford Bacteria | 90,600 | 190,600 | 208,300 | 29,700 | 12,800 | 5,800 | 61,000 | 2,100 | 2,800 | 2,400 | 2,141 | 3,000 |
| Percentage Bacillus Coli Communis | .17 | .50 | .52 | .41 | .86 | .61 | .55 | .89 | .93 | 100 | 86.4 | .56 |

778 The sewage at Alton hangs behind those dikes and is only flushed out at times when the river is flooded. Assuming that the whole of the sewage of Alton becomes mixed with the Mississippi river water and is carried directly towards Hartford with a minimum flow of 25,000 cubic feet per second, in the Mississippi, it will be seen that the sewage of this city of 15,000 people is diluted in a minimum of over one to 70,000.

779 From these figures it will be concluded from the biological results, that the sewage of the city of Alton has no effect on the sanitary conditions of the Mississippi river water at Hartford.

Explains the nature of bacillus prodigiosus.

780 Never found this bacteria in the waters of Lake Michigan, Drainage Canal, Illinois river, or Mississippi river.

On August 31,1900, we prepared in a forty-gallon whiskey barrel, forty gallons of broth culture of this bacillus prodigiosus and grew it for several days in that barrel. On August 31, 1900, this broth, containing over one thousand million
781 bacteria per cubic centimeter, was emptied into the Mississippi river just below the mouth of the Illinois river.

On the way down on the boat samples were taken right straight along, of the Mississippi river water, the samples were collected hourly and studied. Sept. 3rd, four days later, this organism was found in a sample collected in the channel of the river at Alton, but at no other place.

Sept. 20 this experiment was repeated. A barrel containing 40 gallons of bacillus prodigiosus broth was emptied at the same point, and on Sept. 23 this organism was found in a sample collected near the Illinois shore at the Chain of Rocks. On Oct. 18 this bacterium was found in a sample from the laboratory tap in the old city hall, and on October 24 in a sample collected near the Illinois shore, Chain of Rocks.

782 One hundred and seven barrels of prodigiosus broth each containing 40 gallons, were prepared at the old pumping station at the St. Louis water works, by Mr. E. J. Ravold, my brother, and shipped to Lemont, Illinois, and emptied in the Chicago Drainage Canal on the evening of November 6th, 1901.

There were one thousand million bacteria per cubic centi-
783 meter of the contents of the 107 barrels.

All the laboratories were notified and samples were collected every hour of the day and night at the Controlling Works, Drainage Canal, and at Joliet, Peoria, Grafton, on

the Illinois river, and the intake of the water works, Chain of Rocks.

784 Bacillus Prodigiosus was found in samples collected at Intake Tower, Chain of Rocks, December 4th, at 8:45 A. M. Another sample collected at 9 A. M. on Dec. 5, contained the prodigiosus. Found at Grafton, Illinois, Illinois river, December 6th, at 8 A. M. Found again at same place December 7, at midnight.

785 A series of experiments were made with the bacillus prodigiosus to ascertain its longevity in samples of water collected from Chicago river, Drainage Canal, Illinois river at Pekin, and laboratory tap, St. Louis. A summary of the results is as follows: (See record 85.)

787 With these micro-organisms side by side, comparative estimation of the longevity of the bacillus typhosus, and the bacillus prodigiosus, in separate samples of water collected at the same time and place, and kept under the same conditions as to sunlight, temperature and darkness, the bacillus prodigiosus in sunlight, in living waters, that is, non-sterilized waters, lived from two to ten days. The bacillus typhosus in sunlight, and in living waters, non-sterilized, lived from 24 hours to ten days.

In the dark, in non-sterilized, living waters, the bacillus prodigiosus lived from 31 to 53 days and bacillus typhosus from 24 hours to 21 days.

There is a resemblance between these bacterium. They are both bacilli, non-spore forming, and from the above table it is seen that the bacillus prodigiosus is an organism which closely resembles the bacillus typhosus in its power to resist unfavorable surroundings.

788 Q. Now doctor, I will ask you in your judgement, if typhoid bacillus coming from the out-falls of the Chicago sewers into the Chicago river and carried into the Canal, could come into the Intake tower of the St. Louis water works, still retaining its vitality?

A. That will depend upon the time it takes the waters to come from Chicago to St. Louis. But basing my conclusions upon the experiments that I have carried out, and showing that the Mississippi and Illinois river water comes into the intake of the St. Louis waterworks, I am inclined to believe it is highly probable that a typhoid bacillus can live and be carried by water carriage from the Chicago sewers into the Intake of the St. Louis water works, especially in high water conditions in the Illinois river.

ATTORNEY GENERAL HAMLIN—I will enter a motion to exclude that answer as not responsive to the question.

WITNESS—The rapidity of the current does not tend to destroy the typhoid bacteria.

Q. Well, does the volume of water into which a typhoid bacillus may be put affect in any manner its vitality?

A. No sir, it does not kill it.

ATTORNEY GENERAL HAMLIN—I move that that question and answer be excluded as not responsive.

791 In our laboratory experiments, we find that when we take water for instance from the Drainage Canal, that it contains on an average of three or four hundred thousand bacilli to the cubic centimeter. We sow typhoid bacilli in this water and for the first two, three or four days the water bacteria, not the typhoid bacilli, increased enormously, and used up the nutritive material in the flask for food. The results of this destructive action on the organic matter both solid and liquil in the water, results in the production of poisons. True toxin and enzymes and these products seem to act not only deleteriously upon one another but upon the pathogenic micro-organisms that the bacteria in the living waters die much quicker than they do in sterile distilled waters, or than in river waters sterilized.

Q. But in the water in the running streams of course there is no means of judging the results of that?

A. No, the conditions are these: That the toxine or pro-

ducts produced by water bacteria that are deleterious to the typhoid bacillus would be greatly diluted by the flowing water. Besides typhoid bacillus is a mover, and it can swim and get out of the way of anything that would be deleterious to it in a river.

792 Results of experiments as to the longevity of the typhoid bacilli. (See rec. 792.)

799 Q. Now from your knowledge as a bacteriologist and from the knowledge you have of the Chicago Drainage Canal, the DesPlaines river, the Illinois river, the Mississippi river, and the distances, and the speed of the streams, can you state whether or not when the water is running through the Chicago Canal with the sewage running into it, bacteria could come from the Drainage Canal into the Mississippi river?

800 A. Yes, sir. I think the bacteriological experiments indicate that bacteria discharged by the Drainage Canal, especially in high river stages, are carried into the Mississippi river by way of the Illinois river.

Q. Well, do you say that as a fact?

A. Yes, sir.

Q. Now from the same state of facts, above mentioned, as to the rivers and the relative geographical location of the Illinois river, the Mississippi river and the Chicago Canal, etc., do you say, or can you say whether or not the bacteria coming out of the Illinois river, being discharged into the Mississippi river may or do enter the Intake of the St. Louis water works?

A. I think they not only may, but they do, and I base this statement upon the bacteriological investigation that has been conducted by me from 1899 to the present time, from special experiments that were carried out which led me to assert that they do from the mixture of the waters that takes place at the Intake.

From my bacteriological examination the average number of bacteria found in the Intake of the St. Louis water works for the 1900 period— this is Mississippi river water—that is

the samples contain on an average of 72,600 bacteria per cubic centimeter, and bacillus coli communis 62 per cent of the time. That is the average for the whole of that period beginning January 23, 1900, and extending to October.

801 Bacillus coli communis is a pathogenic bacteria. I don't know that it ever does destroy the potability of water. I cannot say that it contaminates water at all; it is an index of pollution. It is never dangerous to the human being except when injected beneath the skin, or when it gets out into the blood stream or lymphatic stream from the intestinal canal. It is one of the most active causes of appendicitis.

802 It (the bacillus coli communis) is not classed as pathogenic bacteria by water bacteriologists, but by the pathologists on account of the pathologic conditions which they produce, which I have already explained, (rec. 801) They are classed as pathologic when they get into the tissues. Pathogenic would be the better word. You can say pathologic too.

Q. Can you state from your examination bacteriologically of the waters in the Mississippi river at St. Louis water works, whether or not that water supply is pure or impure, and if it is impure whether it is a menace to the health of this city?

A. Bacteriologically it is an impure water; it is not a potable water, and it is unfit for human consumption. That is, it flows in the river.

803 Typhoid bacteria is considered one of the highly vitalized and hardy bacteria.

Witness relates the results of experiments made to determine the longevity of typhoid bacilli in various waters under various conditions. (See rec. 803.)

(These experiments tend to show that the typhoid bacteria lives a shorter period of time in ordinary water taken from a stream than in sterilized water.)

807 Drawing conclusions from the laboratory experiments we find that the bacteria (typhoid) live from four days to as high as 21 days in the laboratory flask, in living, non-

sterilized waters. Basing conclusions on them I would be inclined to believe that the bacilli would live much longer in a running stream, living water, than that period.

Q. How much longer?

A. Anywhere from fifteen to thirty days, and that would be a very small limitation.

808 Objection to question by Attorney General Hamlin.

Taking 20 days as the period of time of travel from Chicago to the tap in St. Louis, I think it highly probable from my experiments that typhoid bacilli discharged by the sewage system of Chicago, in the Drainage Canal, could live and retain its vitality the whole, enter the Intake of the St. Louis water works and be distributed to a user of the water sufficiently vitalized to cause disease in a susceptible individual.

ATTORNEY GENERAL HAMLIN—I move to exclude the answer on the ground stated in the objection to the question.

Witness explains various theories explaining the disappearance of bacteria in running water, such as aeration, dilution, sunlight, sedimentation.

813 (Explains method pursued and where typhoid cultures were gotten that were used in experiments to determine longevity of typhus bacillus in various waters.)

817 (Explains apparatus used and method employed in examinations and tests made for the bacillus in the waters of the various rivers during the various periods of examination.)

830 Cause of typhoid fever is typhus bacillus. Cannot be contracted except by taking the bacteria in the mouth or nose and down into the stomach and intestinal canal.

832 The usual method by which this disease is conveyed is infection by water polluted with the dejecta of typhoid fever patients containing the typhoid fever bacillus.

837 From February 8th until the 20th, 1900, the water on the Illinois shore (at the Chain of Rocks) was dark, black. The water on the Missouri shore was fairly clear. The sample

at the Intake showed about an equable mixture of these two waters, and this is demonstrated in the bacteriological examination.

Q. What relation did those dates have to the epidemic of typhoid that ensued in the spring of 1900, that you have heretofore testified about?

A. Within an incubation period the typhoid death rate ran up rapidly in this town in March. Samples were collected in February, and in March 117 cases and sixteen deaths by typhoid occurred in St. Louis, a phenomena that never had occurred previously, and I believe has not since. No such a flare of typhoid in March has ever been recorded in the history of St. Louis, as followed this mixture of this dirty water at the Intake.

I do not consider this water potable and safe for drinking purposes that comes from the Intake tower of the St. Louis water works now, without filtration or without boiling.

837 CROSS EXAMINATION

By Judge Springer.

838 While the river was high the samples from the Illinois river previous to that date, the 10th, were fairly clear, running back a definite time, but this remarkable difference in the water followed a thaw in the Illinois valley and a precipitation of a good deal of water—this whole sweeping out of the Illinois river, came. The Mississippi still remained covered with ice and the Missouri river was covered with ice, this thaw not having reached round to the entire region, and until this thaw did reach the Mississippi river above, towards St. Paul, and finally sweep down onto the Missouri and the waters of all these rivers raised then this difference could be noticed. So at a particular time the Illinois river was high this flood

839 volume was very great and the Missouri and Mississippi rivers were low and the difference in the aspects of the water were recorded.

The first marked condition of discoloration which appeared

at Grafton and on the Illinois shore I think was about the 10th of February, 1900. There was a high stage of water then in the Illinois river. It was a thaw, you see, that was in February. January and February are winter months.

Our work upon the rivers indicated, and we are pretty confident about that, that the first discharge of the Chicago river through the Drainage Canal, at the opening of which occurred on the 16th or 17th of January, reached here by the 29th or 30th of January, and passed, at which time fortunately the Missouri river was very high.

I reached a conclusion as to the cause of this discoloration or polluted condition at Grafton and on the Illinois shore. It was this: This mass of filth that was in the Chicago river and in the Drainage Canal while it was retained there,
840 after the waters of the Drainage Caanal were allowed to stand, or the waters of the Chicago river were allowed to stand in the Drainage Canal for a time without being discharged. The opening of the canal discharged the water over the dam and came rushing down the Illinois valley and traces of it could be seen with the unaided eye for a great distance as the water traveled along. The greater part of the sediment was carried down by a sedimentation, making a black, nasty mud in the stream. It was winter and the anaerobic bacteria were not at work. Consequently they had not destroyed the organic sediment. And then I also ascribed it partially to taking mud that was in behind the dams along the Illinois
840 river and also the muck and slime and sludge that was put into the river by the opening of the Chicago river.

CROSS EXAMINATION.

By Attorney General Hamlin.

847 Would you, as a bacteriologist, be willing to give an opinion as to the condition of the waters in the Illinois river above Grafton in 1899, for that year?

A. For these particular samples at these particular times?

Q. No, for the year 1899.

A. Knowing the stages of the river, I could.

Q. Your opinion is simply for the dates that you took the samples?

A. Just upon the date that I took the samples?

Q. Yes, for no other time?

A. I couldn't give an opinion upon that of which I have not.

Q. From the samples that you took in the Illinois river in 1899, are you prepared to state what was the condition of these waters during that year, or any considerable portion of the year?

A. On none other than the time I took the samples.

Q. Would you, as a bacteriologist, state in your judgement as such, that that would be a fair test of the conditions of the water in the Illinois river above Grafton for the year 1899?

A. I would not.

Q. Do you know how much sewage was carried into the Illinois river from Chicago in the year 1899?

A. I do not.

Q. Do you know whether or not there was practically the same kind of sewage carried into the waters of the Illinois river from Chicago in 1899 as there is now?

A. I do not. I have no information on that subject.

848 The primary cause for the disappearance or elimination of the bacteria known as typhoid bacillus, is due to dilution and sedimentation. The other causes that have been assigned by various observers of water as the cause for the disappearance of bacteria are aeration and agitation, sunlight, oxidation and exhaustion of food supply and planckton.

Q. Do you recognize these causes also, the same as other bacteriologists?

A. I recognize planckton as probably having nothing to do with it. I have no personal experience with it; hence can not make any definite statements. Turbidity of the water has something to with the disappearance of bacteria by sunlight.

851 The effect of the sunlight as an element of the disappearance of the typhoid bacillus would be less on the Missouri river than it would be on the Mississippi or Illinois river, on account of its turbidity.

Our experiments show that the typhus bacullus has a little longer period of life in highly turbid waters than in very clear waters the difference being a few days, five or six I believe.

853 Before the Canal gets to Joliet it widens out into a lake. The water spreads out there for quite a distance, I suppose 300 yards. Part of it is run through turbines, for power and the other part runs over a little dam. There must be a dam there because there is a water fall. There is some sedimentation in that lake or basin. There must be.

855 Assuming that there was a lake at LaSalle as large or larger than the one at Joliet, and that the water moves slowly the current at this point, and through this lake or basin, I would say that there would be a sedimentation. We took samples of water at La Salle in 1901, in October and November. I know that the water spreads out in quite a little lake above Peoria. I understand there is a dam at Henry, Illinois.

856 Assuming that there is a pond or lake at Henry, there would be more sedimentation there.

In any stream of water where there are places that we speak of (lakes or basins) there will be sedimentation. At Peoria there is another lake—the water spreads out over quite an area there. The sewage of Peoria is discharged below this lake. In 1901 when I saw this lake at Peoria the current was slow, very slow. There would be considerable sedimentation there. There are three dams across the river now below Peoria. The first is Copperas Creek Dam. I have been up and down it a number of times in a launch, the Copperas Creek Dam, the dam backs the water or the water is backed up a great many miles and it makes quite a stream, navigable for large boats. In the low water season of 1901 I was in it. We had a launch drawing three and one half feet of water and occasionally it would hit

the bottom and the water was running slowly at that time, and the current in the river was slow. The water was running over the dam in a good volume.

857 There would be considerable sedimentation there. The next dam is at LaGrange, below Beardstown. The water backs behind this dam for quite a number of miles back. The river at the stage I saw it several times was anywhere from 500 yards to a mile wide and the water was deep enough to have the boats run smoothly along up to Beardstown where the water was shallow. There would be considerable sedimentation there. The next dam is at Campsville. Here the water is again dammed and backs up, the current is retarded and a great deal of sedimentation will go on here in this flowing water.

858 As to dilution, calculating upon a 300,000 cubic foot flow a minute and taking all of the sewage of the two million people that discharge into it, we said there would be a dilution of one to nine, but that if four-fifths of the sewage is now discharged into the canal, as it is now claimed, the dilution would be one to eleven.

Q. Do you know as a matter of fact that a certain amount of sewage now is discharged into the canal, that was at that time discharged into the Illinois and Michigan Canal at Bridgeport?

859 A. No.

Q. Well, there is a dilution. Assuming, as I understand, that the sewage of the entire population is carried in at the rate of 1 to 9?

A. Yes.

Q. But assuming that three-fourths—of course the proportions would change correspondingly?

A. Yes, sir.

Q. And if it was only the same that had been discharged for several years, in the Illinois and Michigan Canal, why it would be whatever the proportion of its sewage discharge was

to the number of cubic feet from the lake which was poured into the canal?

A. Yes, sir.

Q. There would be a greater dilution?

A. Yes, sir. There is a large volume of water dis-
860 charged into the Illinois river from its tributaries, from
861 Lockport to Grafton. Never found the typhoid bacillus in any of the waters I examined.

862 In the epidemic of typhoid fever in 1892 in St. Louis the source of the disease was three or four miles from the water works. St. Louis discharges all of its sewage into the Mississippi river, and has done so ever since the city was large enough to have sewers. It seems to me it was 1849 that the first sewers were built, but I am merely trusting to memory for that. The present population is 600,000. I have been
863 told by Dr. Morgner, of St. Charles, which is located 20 miles above St. Louis, on the Missouri river, that that city discharges its sewage into the river. I believe they had once a typhoid epidemic there following the discharge of dejecta from a typhoid fever patient in a hospital, which was carried into the water supply.

865 A typhoid bacillus, if in the water of the Chicago river, would have to travel down the Drainage Canal, pass through all these sedimentations, lakes and ponds that have been mentioned, be diluted with the waters from Lake Michigan and the tributaries of the Illinois and join the waters of the Mississippi at Grafton, then join the waters of the Missouri and pass by St. Louis.

866 Assuming that typhoid bacillus could come from Chicago, if one was found at St. Louis, I couldn't tell whether it come from the sewage of Chicago or came from some tributary of the Illinois—not even if I found it in the water. The chances are that the bacillus traveling from Chicago would lose its virulency sooner than one that had traveled only a few miles.

Q. You spoke of having examined the report made of the typhoid epidemic in Massachusetts. Where was that?

A. Well, that was a report which Dr. Sedgwick made. In that report he makes the statement that the evidence shows that there is no stream long enough to purify itself from sewage even put in at its source.

867 Q. Is it not a fact that as a result of that report, the legislature of Massachusetts passed a law providing that there should be no sewage discharged into the streams in that state less than 20 miles above the intake of water supplies?

A. I think a law of that kind did come into force, following that.

Q. Do you say as a bacteriologist that in your judgment that limitation is a reasonably safe one?

A. It is an absolutely absurd one, it is not based on bacteriological evidence at all.

868 A very small percentage of typhoid fever epidemics show the source of typhoid fever from water pollution to be exceeding fifty miles. I have one in mind. That was the dredging of the St. Clair river, and the typhoid fever epidemic following in Detroit; that has been reported by Dr. Williams. That occurred when the river was being dredged. I don't know what the distance from the original typhoid case was to the waterworks at Detroit, but I think it is more than 50 miles.

869 I have Mr. Williams' report. I understand it was something over 60 miles.

Q. Isn't that the most extreme case on record?

A. My memory serves me with no other case at the present time. I would say that 95 per cent of the reported cases of typhoid fever epidemics or a large increase of typhoid fever from water pollution, has been shown to be less than 50 miles. The sewage of Kansas City is discharged into the Missouri River after resting in so-called cess-pools for a time. I have been told that the sewage of St. Joseph, Mo., is carried into the Missouri River. The sewage of Leavenworth and the hospitals there is carried into the Missouri River.

870 There is only one safe way of purification of waters and that is by filtration.

Q. How much filtration in addition to what you have here in St. Louis, would have to be installed in your waterworks system to make it a successful system of filtration?

ATTORNEY GENERAL CROW: Objected to as irrelevant.

A. That is not known by anybody. A body of engineers and expert filter men have been at work on that problem and they have made recommendations without having carried out an adequate series of experiments on the water to ascertain the facts connected with it and nobody knows how to filter this water supply. I do not mean to say that a system of filtration could not be installed here, but it is not known how best to filter this water and what it will cost. I do not know how best to filter this water.

871 In the reservoir system we have here there is some seventy per cent of the bacteria removed from the water, to the consumer; at a definite period of 1901, we found as high, I believe as 90 to 95 per cent to the consumer, of bacteria removed.

872 I have seen the sewage discharging from Quincy, Keokuk, Rock Island, Burlington and Davenport, into the Mississippi River. I think all of them do. St. Paul and Minneapolis also discharge their sewage into the Mississippi River. I know that there are several rivers discharging in the Mississippi. Of the towns that discharge their sewage in the Missouri River, I know of Kansas City. I don't know of St. Joe by personal knowledge, but I know they discharge their sewage into the Missouri and I know Kansas City, Leavenworth, St. Charles, and Jefferson City do.

873 It is a fact that the Mississippi, Missouri and Illinois rivers are used by the inhabitants of the various towns along those respective rivers, for the purpose of depositing their sewage in each of the rivers.

St. Louis discharges its sewage into the same common

drainage that the inhabitants of the other rivers do. The first sewer was constructed in 1849.

874 Population of St. Louis, within the corporate limits that discharges sewage in the Mississippi river is 600,000.

875 The water consumption is about 130 gallons per inhabitant, making 78,000,000 gallons every 24 hours.

Basing St. Charles' population at 10,000, water consumption at 100 gallons per day, they would discharge 1,000,000 gallons of sewage per day from St. Charles.

Kansas City has a population of 200,000, basing a calculation of pumping 130 gallons—or make it 100 gallons per inhabitant, would make 20,000,000 gallons of sewage per day.

876 Explains cause of typhoid fever and how that disease may be communicated. One of the means of communication is milk.

877 St. Louis gets a large part of its milk supply from the rural districts of Illinois and Missouri. In my work as sanitarian I have visited the companies furnishing milk supply. In nearly all of these places they steam sterilized the cans before sending them away or they drive them into boiling hot water with streaming steam in it before sending the cans away from the city. I never visited the Union Dairy Company and do not know whether they have any system of sterilization. They handle a large quantity of milk. If the cans are not sterilized I would say that it was a gross act of negligence, owing to the fact that there is a possibility of typhoid bacillus being conveyed that way.

878 I know that there are accounts in the literature of typhoid epidemics caused by the milk supply.

I know in the books where a man washed the milk bucket with this diseased water and not entirely drained and the typhoid bacilli got into the milk.

881 Isn't it a fact that you know that the Illinois river only contributes about one-tenth of the volume of water that is contributed by the Mississippi above Grafton and the Missouri at its mouth?

A. In these low river stages this would seem to be the case because I find that just below Grafton in the Mississippi the minimum flow of 24,858 cubic feet per second was noted on January 11th of this same year. So that would give the Illinois there 2,360 cubic feet per second. That would be about one tenth.

882 Witness is asked to verify tables showing per centage of death rate from typhoid, per cent of cases to population and of deaths to cases for the years 1897-8-9-1900-01-02.

883 The watershed of the Missouri river embraces 530,000 square miles.

884 The drainage area of the Illinois river is 27,914 square miles. The drainage area of Illinois as compared with the drainage area of the Mississippi and Missouri is very small.

CROSS EXAMINATION

By Mr. Drennan.

885 The principal water-born pathogenic bacteria are typhoid, cholera and dysentery and I found none of these in the Illinois river.

Q. Is'nt it recognized as a scientific proposition that these pathogenic germs do not thrive in sewage?

A. No, it is not entirely that way. It depends upon the character of the sewage. Some observations by different men show that the typhoid bacillus has lived as high as five months in sewage, while others but a few days. So you see it depends upon the character of the sewage at the particular time.

I made no investigations as to the sewage there in Chicago, and I cannot answer as to that.

886 The septic tank system is still in its experimental stage. For certain classes of sewage it does not seem to be entirely practical. It is very efficient in some localities and not at all so in some others.

CROSS EXAMINATION

By Judge Springer.

(Witness is asked about 32 pathogenic bacilli mentioned in the works of Abbott and Frankland.)

889 Of the list mentioned, I found in the waters of the Illinois river, the bacilli coli communis, proteus vulgaris, proteus mirabillis, proteus zenkari and I think we once found bacillus pyocaneus. I don't remember whether I found these in the Missiuri river water also. I found the proteus zenkari one time in the Missouri river water oposite Bellefontaine. I found none of the others except the bacillis coli communis. They produce no disease in man; they are non-pathogenic to man.

Q. Are they regarded as injurious to drinking water?

890 A. They are related somewhat to sewage producing, when associated with others. But not of themselves.

Q. Then your conclusion, as to the dangerous quality of bacteria in the Illinois river, was not based upon the poison, the actual germs that produced disease there, but other germs which were kindred, or sometimes found with them?

A. Yes, sir.

The same is true of the Missouri river about the mouth of that stream and of the Mississippi river above the mouth of the Illinois. I found substantially the same conditions existing in all these three rivers, only more of this sewage bacteria in the drainage canal and Illinois river than we found in these others. We found them a greater number of times.

Q. Is there any means now known of obtaining absolute proof of the hygenic quality of water supply?

A. Well, bacteriology will indicate the presence or absence of bacteria.

Q. Is that sufficient to determine the potability of the water supply itself?

A. Yes, it was used by the German government. All these

samples that I have taken and have examined must be
891 considered in the light of the stage of the river and rainfall at the time.

Q. In order to obtain a perfect, or approximately perfect knowledge of the bacteriological conditions of running water, would it not be necessary to take samples every day in the year and under precisely similar conditions for those days in order to make your calculations reliable?

A. Yes, sir, that is what we did.

Q. Every day in the year?

A. Every day in 1900 from January 23d to October 11th, I think. For 1901 during the months of September, October and November. They covered only one sixth of the year.

892 During that period of investigation in 1901, from September to November there was practically no rainfall in the Illinois river basin, and the same obtained on the Missouri and Mississippi river basins. It was a time of drouth when all the rivers were depending on the springs that were discharging into them, and they remained practically level, as I showed on the charts. The Chicago sewage has shown less after running a definite number of miles, there is less trace of it in the Illinois river than there is at higher periods. It showed fewer bacteria than were originally carried by the drainage canal after running to Peoria and then to Grafton than it did in the season either following a freshet or when the river was high but steady.

Q. Did the drainage from the farm region and from the pasturage of the country districts generally, if that was coming into the stream, wouldn't it be more peculiarly a condition created by the ordinary flow of water from Lake Michigan and the Chicago canal?

A. Yes, sir.

Q. So that would be a better time for determining the influence of the Chicago water on the Illinois water?

A. This particular time was an extraordinary time, the 1901 period was an extraordinary condition, there was very

little water in the river other than that discharged into it by the drainage canal.

893 It is true that water in stream is, by all recognized standards of potability, at one time and another, the subject of contamination. Bacteriologically, absolutely pure water there is none except that of boiling springs. All water from whatever sources, save from hot boiling springs, contains more or less bacteria, from very few numbers up to large numbers. The presence of bacteria in water is not of itself an evidence of fecal pollution, but simply evidence of food supply for bacteria to grow upon. I have found bacteria in fresh fallen snow, in hail and in rain water.

894 There is no such thing as running water, such as is found in rivers and streams of any country, being free from bacteria.

895 It is true that the conditions bacteriologically considered, of the Illinois, the Mississippi and Missouri rivers at the places where I have taken samples of water, are very similar to the conditions found in rivers of similar size in this country and Europe. This is true of all the periods of which I have referred as the 1st, 2d and 3d period of investigations here. I would have been terribly surprised had I not found bacteria in these waters. The rivers generally in this country and in Europe are in such a condition as to render them unfit for water supply for cities without some kind of sedimentation or filtration. That applies to all the rivers to which I have referred in my examination here.

Q. As a bacteriologist, then, you would not recommend supplying cities with water taken from the running streams of this country without some system of sedimentation or filtration being adopted for the purpose of removing the bacteria?

896 It is possible from my observation of conditions, to prevent sewage from getting into running streams. They do that effectually at Berlin with their irrigation farms; in Glas-

contain the sewage of any community ,it is unsafe to drink and no matter how far above the sewage is thrown into the river it is unsafe to drink that water unless it receives some treatment for the purpose of removing bacteria. The danger would be greatly minimized if you eliminate the city sewage, but still the danger would be there.

899 The epidemic at Lausen, Switzerland, was caused by contamination which existed only a mile and a half away from the place of the epidemic. The same conditions existed at Chatterham, England, to which I referred. The contamination was direct in the water supply, in the well itself. At Plymouth, Pa., the contamination was direct into the water supply. The epidemic at Zurich, Switzerland, was caused by contamination of a lake in the immediate vicinity. At Springwater, N. Y., the cause of pollution was in the immediate vicinity. Lowell, Mass., epidemic was caused by contamination of the Merrimac river, close to the city. Same at Sault Ste. Marie. Epidemic of typhoid at Elmira, N. Y., in 1896, the contamination came from the Chemung river and there were some places above, the highest above being 50 miles and the nearest 16 miles, and Prof. Hill says it must have come from some of these localities. Epidemic in Paris, France, in 1895, occurred from pollution in the immediate vicinity of a camp of soldiers.

902 Same as to epidemics of San Francisco, Calif., Denver, Colo., and Middletown, Conn. Stanford, Conn. epidemic of 1895 was caused by the use of milk.

903 From the recorded instances, which are the most classes, if I may use that word in this connection, as to typhoid epidemics in this country and Europe, all of them were caused by conditions which existed in the immediate vicinity of the place where the epidemic occurred.

904 The epidemic at Detroit caused by dredging of the St. Clair river, 67 miles to Port Huron, the course of the epidemic, is the only authenticated case on record where the place of pollution and place of infection were as far apart as

gow, Scotland, I drank the sewage that had been chemically treated before it was discharged into the river Clyde; at Paris the same thing is done after it is treated, and there are well known methods of purifying sewage before discharging it into a stream.

There is a greater number of bacteria per cubic centimeter in river water during flood time for the reason that all surface soil contains millions of bacteria growing upon nutritive matter that there exists—vegetable matter—as a rule these bacteria are washed into the running streams by the rainfall, so the bacteria at these particular times are soil bacteria in preponderance as a rule.

897 This contamination is not sufficient to condemn all our running water for potable purposes because they are non-pathogenic germs. If there was any town in the vicinity of this city that had a typhoid fever epidemic and the flood came and washed these typhoid germs into the river, that would contaminate the stream. If this was thrown out on the soil or from privy vaults it would sweep out into the stream in the mass of volume of water that washed all that surface and be carried along the Lord knows how far.

898 If a mass of feces should be thrown out on the sides of a reservoir, that at any time would be a dangerous thing. That may occur at any time in all the rural districts contiguous to the rivers. At Plymouth to which I have testified, there was a reservoir but it is such a very minute thing where there is a vast volume of water.

It moves the bacteria farther apart, that is all, they are still alive and they are still dangerous.

As a chain is not stronger than its weakest link the water supply is not better than its weakest place. You ought to have a water supply that would be good at all seasons, at all times, and under all conditions.

Q. Can you have that if you take your water supply from the rivers without filtration?

A. There is danger from a river that may contain, or does

67 miles. I know of no ascertained case where the infection was brought further than the case I have just mentioned.

908 November 6, 1901, 107 barrels of prodigiosus broth containing more than one thousand million bacteria per cubic centimeter were emptied in the Drainage canal at Lemont.

909 The record shows one side of a cube representing a cubic centimeter.

919 The first prodigiosus bacteria was found at the intake tower, Chain of Rocks, December 4, at 8:45 A. M. I found only one. That is, I found one colony, I believe. I don't think I found more than one in a cubic centimeter. I found another on December 5th.

920 The water was cold and the chances are that there was very little growth, if any, of bacterium as it floated down the river, it simply depending upon its inherited vitality to keep alive, so I will state emphatically that I think there was no growth of the bacteria at that time in the water. The individual bacterium put into the canal at Lemont undoubtedly floated all the way and lived.

921 Found it again on December 8 in the intake tower. Found it at Grafton, Illinois, in the Illinois river on December 6, at 8 A. M. Next sample was found by Collector Homer at Grafton, Illinois, Illinois river, at midnight, December 7th. That was all the times that I found it. I never found it again —I continued searching the tap water in the laboratory until March 1, 1902. I therefore found it twice at Grafton and three times at the Chain of Rocks, which would be five times out of 1,100 samples taken for the purpose. This bacterium has never been found in the waters of the United States.

934 Bacteria known as saprophites are useful in the arts. In the production of alcohol. In tobacco culture. In beer. In the production of butter and cheese.

938 All unsterilized milk as it is furnished in the milk cans in the market, would hvae more or less bacteria.

939 The typhoid fever germs, if found in milk, would be from

extraneous introduction as milk before it comes from the cow is practically sterilized.

942 It has never been proved satisfactorily that disease bearing germs increase in number in the water—in running water.

944 If you had one hundred men with typhoid fever discharging sewage into the river at the mouth of the Illinois river, at Grafton, the danger to St. Louis would be much greater than if one hundred men were discharging their typhoid fever discharges into the Illinois river at Lockport from the Drainage canal.

Q. Suppose that there should have been 20 persons who died of typhoid fever within the year 1900 or 1901 or 1902, and that there was a corresponding number of persons in the same vicinity in the village who, recovered from the disease and the dejecta of all persons, those who died and those who lived, was deposited in the Illinios river at Grafton, what would you say as to the probability of such a deposit producing typhoid fever in St. Louis?

A. There is a possibility of such bacteria being carried into the St. Louis intake and producing disease in St. Louis.

945 Q. Now, suppose that four persons were afflicted at the same time and the urine and dejecta were deposited in the Missouri river within 30 miles of this city would not that be a sufficient number to create and probably cause at least disease germs to appear in the St. Louis intake.

A. The small number that would reach the consumer would be extremely small from these four people, from the daily discharge of four people into the Mississippi river, which we saw in a low river stage discharges something like 24,000 cubic feet a second so the separation of the bacteria which would be discharged by 4 patients into that volume of water would be very wide apart and it is possible that some of them might be carried into the intake tower and through it into the

distribution system of the city to susceptible individuals, but the danger would not be very great.

Q. Take the city of Alton, 25 miles from St. Louis. Take the same conditions, what would you say would be the danger to St. Louis from the near proximity of cases of that kind?

A. We saw that the dejecta of each one of the inhabitants of Alton when discharged and mixed with the waters of the Mississippi river passing that point would be one to 70,000 and that we trace very little evidence of the sewage of Alton at Hartford, seven miles below, bacteriologically, and consequently it would be again a very remote possibility of having bacteria coming from those patients into the intake.

946 If you were afflicted with a typhoid epidemic in St. Louis where as many as 200 persons were dying in a year during the recent years and you could not trace the cause to any other source than one which you have imagined might be in existence at Alton, would not that sufficiently account for any trouble?

A. No, I think not, sir. Two hundred deaths would mean three thousand cases at least of typhoid fever in the city and that is a great many sick at the same time out of a population of 675,000 to 700,000 with 90 per cent of the bacteria removed by the reservoirs to those who consumed the water. It would take a much larger infection than four people could produce even if above the intake. It is worthy of consideration and is a factor to be considered in this connection in trying to trace the source of a typhoid epidemic every fact must be brought to light.

From St. Charles to the intake is about 50 miles. If 20 people who died in St. Charles a year and a corresponding number of patients who survived discharged their dejecta both liquid and solid, in the Mississippi river, owing to the dilution there would be the remote possibility of the bacteria reaching the intake.

948 If a lively colony got into the intake you might get several millions into the waterworks from that source?

A. And 90 per cent taken out by the reservoirs before they got to the consumer, so it would leave a few to be distributed throughout the city.

949 RE-DIRECT EXAMINATION

By Attorney General Crow.

Dilution does not in any way destroy pathogenic germs.

Considering my knowledge of the water supply of St. Louis before and opening the Drainage canal I think the water supply at the intake tower of this city has been rendered less wholesome and safe for domestic and primary use than before the opening of the canal. I can prove it chemically and bacteriologically. Formerly the sewage remained in the Chicago river in a stagnant state, long enough to become purified, and to kill the pathogenic germs. Now the current there is three miles an hour and the chances of pathogenic bacteria vitalized and strong as they come from the bowels of an individual being carried down to St. Louis water supply is infinitely greater than when the pumps were at work at Bridgeport.

951 Bacillus carried a great distance would be less virulent, but would cause typhoid fever in a susceptible patient the same as those carried a short distance. The difference being that the disease produced by a sea of typhoid bacillus would be of more severe type than that produced by bacilli carried some distance.

953 Sand or any other filtration is only a relative preventative of typhoid fever. The effect is to greatly minimize the danger.

954 Basing conclusions on dredging such as that at Detroit, it would seem that typhoid bacilli will retain their vitality a great number of days in the sludge that exists in the bottom of a river or mouth of a river.

Where sewage is found in a stream it is presumed that pathogenic bacteria may be there also because sewage polluted water contains the discharges of human beings and if there by typhoid or other diseases among them like diseases will follow

in those drinking the water. Aside from the repulsiveness of drinking sewage that comes from aesthetic reasons the real danger in sewage comes from the germs. The ordinary scientific tests as to whether contains sewage pollution are microscopic, chemical and bacteriological examinations. It takes the three to determine the potability of a water supply.

955 Authentically the typhoid bacilli has been found in running waters probably a hundred times in all the history of the world.

956 Q. As a bacteriologist and hygienist I will ask you if you consider it safe for the citizens of any city to sewer into running streams the waters of which are used for primary and domestic purposes by those below.

A. I think it is a dangerous thing to do to use that water. As I remember the conclusions of the English River Pollution Commission, which worked eight years, they were something like this—that the evidence is overwhelming that sewage polluted waters are dangerous to drink and that no river in England is long enough to purify itself of sewage, consequently of pathogenic bacteria even if put in at its source.

Q. Did you find in the waters of the Illinois, DesPlaines and Mississippi rivers coli communis in greater numbers in a flood stage than in ordinary seasons?

A. In flood stages the percentage was less than in low waters. The typhoid death rate in Chicago compared with other cities of a similar size in this and other countries, is very high. The population of Chicago according to the census of 1890 was 1,148,710. The deaths in Chicago, from typhoid fever for the years indicated, are as follows: 1891, 1,997; 1892, 1,489; 1893, 670; 1894, 491; 1895, 518; 1896, 751; 1897, 437; 1898, 636; 1899, 442; 1900, 337; 1902, 509; 1902, 597—first ten months of the year only given.

In 1893 the water was taken from the four mile crib. Prior to that it was taken from small cribs not very far out. There has been a steady increase in deaths since the opening of the canal.

961 RE-CROSS EXAMINATION

By Mr. Springer.

965 CHARLES LEWIS STEVENSON examined by Mr. Woerner. Am a traveling man. Collected water samples under direction of St. Louis Water Department. Describes method pursued and where samples were taken.

968 EDWARD H. KISER, direct examination by Mr. Crow. Am professor of chemistry in Washington University, St. Louis. Have been occupying that position since the fall of 1899. Came here from Bryn Mawr College, near Philadelphia, Pa., where I had been 14 years. Was professor of chemistry there. Prior to that time was instructor in chemistry in Johns Hopkins University at Baltimore for about 18 months. I was Fellow in Chemistry previous to that in Johns Hopkins University for two years. I was graduated from Swarthmore College, Pa., in 1880, taking degree of Bachelor of Science and took degree of Master of Science in 1881 from same institution. In 1884 took the degree of Doctor of Philosophy in Johns Hopkins University, and studied in Germany in the summer of 1884, at Freiburg, in Saxony, and in 1887 Gottingen University, and in 1894 at Heidelberg, in Germany. In Germany I studied chemistry.

969 I was called upon in January, 1900, by the Water Commissioner of St. Louis and the City Chemist, to make an examination of the waters of the Mississippi river at the intake tower of the St. Louis water works, of the Missouri river, and of the Mississippi river about the mouth of the Missouri, the Illinois river, the DesPlaines river and the Chicago Drainage canal.

970 (Witness states his experience in examination of various waters.)

972 (States how waters under consideration were examined and methods pursued.)

974 I made eight determinations in the analysis of water. First, of the total solid matter in the water; second, the

amount of free ammonia; third, the amount of albuminoid ammonia; fourth, the total ammonia; fifth, the oxygen consuming properties of the water: sixth, the nitrogen present as nitrates; seventh, the nitrogen present as nitrites and eighth, the chlorine. For the first five determinations we used the water in an unfiltered state. For the last three we used filtered water.

980 We began the analyses of these waters on January 24,
982 1900. I analysed these waters to determine the presence of nitrites, nitrates, albumoid ammonia, free ammonia and chlorine and the amount of oxygen consumed. The presence of nitrites and free ammonia I regard as of chief importance for the reason that the presence of measureable quantity of nitrites in drinking water is often regarded as a sure sign of contamination, and a chemist finding a measurable quantity of nitrites in water would condemn that water as unsafe for drinking purposes. And so free ammonia, likewise, is of great importance in judging of the sanitary conditions of the water for the reason that the first product produced by bacteria in decomposing sewage is free ammonia. We always find a quantity of free ammonia in sewage, so the chemist lays special stress on these two constituents, namely, nitrites and free ammonia. Free ammonia is ammonium carbonate, or ammonium chloride existing in the water, that has been formed by the action of bacteria upon nitrogenous organic matter. Free ammonia is absent from pure water.

983 The presence of these nitrites indicates there is decaying vegetable or animal matter in the water—and the same with free ammonia. That is the reason these two chemical substances are indication or warning to the chemist that the water should be looked upon with suspicion.

I have a record of the fluctuation of the nitrites in the reservoir of this city (St. Louis) from January 14, 1900 to October 11, 1900. We made daily analyses and from them made daily averages, and from the daily averages we made weekly averages. I have those weekly averages of the parts of nitrogen present in one million parts of water in the form of nitrites.

984 Table No. 1 is read, showing result of examination of reservoir at St. Louis water works from January 24, 1900 to October 11, 1900, and giving nitrites, parts per million.

986 The average amount of nitrites during the period from January 24, 1900 to January 31, which was the time prior to receiving the water fom the drainage canal, was .0044 parts per million.

Following is the average for the months indicated, at the same place: February, .0133; March, .0107; April, .0180; May, .0055; June, .0032; July, .0017; August, .0021; September, .0013; October, .0021.

The following is the maximum: February, week of 21st to 28th, .0240; March, week of 21st to 31st, .0130; April, week of 14th to 21st, .0260; May, week of 1st to 7th, .0097; June, week of 1st to 7th, .0040; July, week of 14th to 21st, .0021; August, week of 14th to 21st, .0035; September, week of 14th to 21st, .0016; October, week of 1st to 10th, .0021.

987 Plate No. 1, presented. Curve shows the changes of nitrites in the reservoir water of St. Louis from October 1st, 1901 to November 30th, 1901.

988 Chart is marked Complainant's Exhibit No. 23. This table and this chart show that early in February the quantity of nitrites in the reservoir water began to increase very materially, and the water of the reservoir was in a highly polluted condition. This pollution continued during March and during April. About the end of April and beginning of May the quantity of nitrites materially diminished; and then during he summer months it was low, and in October they began to increase again, in 1900. Then in 1901 we continued the analyses, and found that they were again higher.

989 The abnormal increase in February in nitrites in the reservoir water we attributed to the coming down in the Mississippi river of large quantities of sewage. As shown by analyses made at other points on the Mississippi, at Alton and Grafton on the Mississippi, and on the Illinois, it was shown that they came down the Illinois river. Our analyses point to

the Drainage canal as the source of them. The decline in May, June and July from the pollution or the falling off in the quantity of nitrites in the reservoir water in the spring months was coincident with the heavy rains and the high stages of the river. This caused a greater dilution of the large volumes of rain water flowing into the rivers—the quantity of nitrites was materially diminished in the early part of May and during June, and in the summer months the high stages continued.

990 Table No. 2 shows the weekly averages of the nitrites of the water at the intake tower in October and November, 1901. (See rec. 990.)

The maximum amount in October was in the week of October 28 to November 4, and the amount was .0084. The maximum amount in November was in the week November 11 to 19, and the amount of nitrites was .0143.

991 In 1901 there was an increase over what had been found in 1900.

When the amount of free ammonia in river water arises above .045 per million, the water is regarded with suspicion, and it is generally recognized that such water is polluted. That is not a hard and fast rule, however, that is applied under all circumstances. That will vary with the local history of the water and the local surroundings. For instance, a water might contain more free ammonia than that and it might be from a source that was absolutely harmless. To illustrate, the sale might be placed in such juxtaposition to a well or reservoir that it would cause a much higher per centage of free ammonia and be absolutely harmless from a sanitary standpoint.

992 I have made weekly and monthly averages of free ammonia in reservoir of St. Louis waterworks between January 24, 1900 and October 11, 1900, which is table No. 3. (See rec. 992.)

995 These weekly averages and also monthly averages show great increase in the free ammonia immediately after the last week in January, and this high ammonia continued throughout the months of February, March and April. After the 21st

of April there was an improvement in the water, which continued until the middle of June, and after June, there was a slight increase in July and August, and again in October. So that throughout the summer the water was much better than it had been in February and March.

996 Chart No. 2 offered in evidence.

This is a chart on which there is plotted a curve, showing the changes in the amount of free ammonia in the reservoir water, St. Louis, from January 24, to October 10, 1900. This table and chart shows a very great increase of free ammonia immediately after the first week in February. The quantities of free ammonia increased very considerably in the reservoir water in February, 1900. It extended into March and April and began to diminish then just as previously the nitrites were diluted by the spring rains, so we find that the ammonia was diluted and the quantity found in the reservoir water was very much less during the spring and summer months than it had been immediately after the opening of the Drainage canal. This increase was caused by pollution which we traced to Peoria and farther beyond Peoria up to Joliet and Lockport.

997 I made averages of the free ammonia found in the intake of the St. Louis waterworks during the months of October and November, 1901. (See rec. 998.)

999 For table No. 5 see rec. 999.

This table shows that there was a decided increase in February in the number of nitrates, and also in March. Then a gradual decrease in April and that decrease became more pronounced in May. There was a slight increase in June, and a decrease in August and September. In October we find the value very near the same as at the beginning. The increase began about the time when the water of the Drainage canal reached St. Louis. Then again as in other cases, when the spring floods came, there was a diminution in the quantity of nitrates found in the reservoir water.

1001 Table No. 6 is a record of the nitrates found at the intake

from October 1 to November 30, 1901. Plate No. 3 contains a curve showing the changes in the amount of nitrates found in the reservoir water. There was less nitrates in 1901 that in 1900. This would indicate that the water was more impure because the organic matter had not been completely oxidized. There were more nitrites but less nitrates in the water examined in 1901 than there was in 1900.

Exhibit 25 offered in evidence.

1003 The fourth form in which nitrogen is found in water is as albuminoid ammonia. That is not found in water in its natural state free from pollution. It is the product of decomposing nitrogenous organic matter. That albuminoid ammonia would be derived from both vegetable and animal matter in water. The reservoir water of the city of St. Louis is turbid at nearly all times of the year. That means that it contains washings of the surface of the earth, vegetable matter that has been carried in by rain fall.

1004 I made an investigation of the reservoir water to determine the quantity of albuminoid ammonia contained in it from January 24, to October 11, 1900.

Table 7 shows the average results.

1005 Maximum results for same period.

1007 Table 8 shows the results of examination at same place for months of October and November, 1901.

Plate No. 4 contains a curve showing the changes in the amount of albuminoid ammonia in the reservoir water.

According to these figures the maximum pollution occurred in March and April, 1900.

1008 The minimum was about the middle of June, 1900. There was an increase after that again in July and in August, and it remained pretty high in September and in October.

Taking all of the result of the chemical analyses made by me in the period from January 24 to October 10, 1900, the conclusion is that the water became suddenly badly polluted about the first week in February, as is shown. That is shown by a very large increase in the quantities of free ammonia and

nitrates in the reservoir water and this pollution continued during the months of February and March and began to diminish in April. This was coincident with the increase in the volume of the rivers. In the succeeding year the analyses show that the water was certainly in no better condition and as far as nitrites and free ammonia are concerned, the water was more polluted in 1901 than in 1900.

Complainant's Exhibit 26 offered in evidence.

1009 This water would not be classed as a safe drinking water owing to the large amount of decomposing organic matter in it. The warm weather of the summer assists in oxidization in water. All chemical changes proceed more rapidly at higher temperatures than lower temperatures and the bacterial action is greater in the warm seasons of the year.

1011 When we find free ammonia and nitrites present in considerable quantities we regard the pollution as of animal origin and caused by sewage. Albuminoid ammonia on the other hand is not in itself so characteristic of polluted waters because albuminoid ammonia may be there of vegetable origin. Nitrogenous organic matter is the starting point from which the albuminoid ammonia as ammonia is gotten out of the organic matter in water by treating it with an alkali and by potassium permanganate, and in that way we distill off ammonia from the organic matter which is not there as ammonia in the water. We decompose what organic matter is left in the water by chemical agents and measure the ammonia that distills over. For that reason albuminoid ammonia is not an index of any particular pollution in water.

1012 There is a lower form of pollution of water that contains nitrates and nitrites. The nitrites are a final product. When we find very little ammonia and no nitrites, and a good deal of nitrates, we know the water has been polluted at one time, and it has gone through the process of oxidation so the pollution has been rendered comparatively harmless. The oxidization is brought about by bacteria, we look upon it as a process of the transference of oxygen from the air to the organic

matter in the water so that the complex organic substances are resolved into simple inorganic material. I look upon the original form of polluted matter in water as a complex combination of carbon, hydrogen, oxygen and nitrogen. That would represent, for instance, albuminoids, albuminous substances that are in water, compounds of that kind are in sewage, and the bacteria break up those substances and we get ammonia, a part of the nitrogen is evolved as ammonia and then afterwards the bacteria transfer the oxygen from the air to the nitrogen that is there, forming nitrites and then transforming the nitrites into nitrates, by adding still more oxygen. The analysis of the water that I made at the intake of the reservoir was for determining the presence of these four bodies, nitrites, free ammonia, albuminoid ammonia and nitrates.

1013 I also examined for the purpose of determining whether there was chlorine in the water. I have the record of chlorine at different points. I made a comparison of the water on the Missouri and Illinois shores opposite the Chain of Rocks for the purpose of determining whether the river at the intake was of homogeneous character, whether the water was of the same character on both sides of the river. I found a marked difference in the character of the water, chemically, water taken at the Missouri shore opposite the Chain of Rocks and water taken at the Illinois shore opposite the Chain of Rocks. I found that there was a difference in the nitrites.

Table No. 9 shows the parts of nitrites per million from January 24 to October 11, 1900, at the Missouri shore and at the Illinois shore opposite the intake.

For comparison of the water on Illinois and Missouri shores, see rec. 1014.

1017 Table No. 10 shows result of examination for nitrites at same places for October and November, 1901.

1018 Plate No. 6 shows a curve giving the variations in the amount of nitrites at the Illinois shore opposite the Chain of Rocks. Plate No. 5 shows the variations on the Mis-

souri shore. These two plates were made to illustrate the examinations as disclosed in table No. 9.

Plates offered in evidence as Complainant's Exhibits 27 and 28.

1019 It will be seen that the nitrites in January are nearly twice as great on the Illinois side of the river as on the Missouri side. They begin to approach one another in February. They are about equal in March, but in April the quantity on the Illinois shore is twice that on the opposite side and this increase was maintained throughout the summer and it became six times as great in September and October, 1901. In February, 1900, there was a rise in the Illinois river coincident, I think, with the coming down of the water of the Drainage canal. From my recollection the Missouri was low and the Mississippi river was low. During the period that we made the analyses there at the eastern shore of the river, the water was from four to five times more polluted than the water on the Missouri shore as shown by these nitrites—by the quantity of nitrites.

1020 From the fact that the amount of nitrites in the reservoir was greater than that in the Missouri river on the Missouri shore and less, somewhat, than that on the Illinois shore, we naturally conclude that it was a mixture of the two waters—in fact not only the nitrites but all of our determinations showed that the water taken in at the intake is a mixture of those two waters. The chemical analyses indicate that the water on the eastern shore at the intake tower is Mississippi river water and the water on the western shore is Missouri river water.

Now on the Illinois shore in January, 1900, the average amount of nitrites was .013 and in February it went up to .0187 and it came down somewhat in March but it went up very high in April, .308 and gradually came down during the summer but throughout the entire summer it was from four to five times as great as on the Missouri shore. The average value of the nitrites was .0068 in 1900; in September, 1901, it was .0125, nearly twice as much. Comparing the analyses made at Bellefontaine with

the analysis at the point opposite the intake on the Missouri shore it discloses the fact that the water running along at the point on the Missouri shore of the intake is Missouri river water.

1021 I made an analysis at Hartford. The anaylsis showed that was Mississippi river water. I have a table showing the average of free ammonia on each side of the river at the Chain of Rocks. It is table No. 11. (See rec. 1021-2.)

1024 Plate No. 7 shows a curve giving the variations in the amounts of free ammonia at the Missouri shore at the Chain of Rocks. Offered in evidence as Complainant's Exhibit 29.

1025 This plate No. 8 shows the same thing for the Illinois shore at the Chain of Rocks. Offered in evidence as Complainant's Exhibit 30.

Table No. 12 shows the average amount of free ammonia found on each side of the river opposite the intake tower of the St. Louis waterworks in October and November, 1901. (See rec. 1025.)

1026 These tables show that much larger quantities of free ammonia are found on the Illinois side of the river during the months of January, February, March and April. During the remaining months both sides are practically alike as regards this form of nitrogen.

The analyses made in 1901 shows the quantity of free ammonia was greater on the Illinois Shore than on the Missouri shore.

Table No. 13 shows the amount of nitrites found opposite the intake, first on the Missouri shore and second on the Illinois shore. (See rec. 1026.)

1030 Nitrates found at same place in October and November, 1901. Plates 9 and 10 contain curves giving changes in amount of nitrates at Missouri shore and Illinois shore, Chain of Rocks. Marked Exhibits 31 and 32 for Complainant.

1031 There were more nitrates as a rule on the Illinois shore than on the Missouri shore.

Considering all the facts heretofore set out, with reference to my chemical work, the water is most polluted from a chemical standpoint on the Illinois side.

In regard to the sanitary character of the water, the Missouri shore is the better water.

The chemical analyses showed that the water on the Illinois shore is Mississippi river water; and the water on the Missouri shore is Missouri river water.

The chemical analyses showed that the water in the reservoir was a mixture of these two waters.

1032 From a sanitary standpoint the water of the reservoir is better than the water from the Illinois shore at the intake. The water in the reservoir is worse than that of the Missouri shore.

1033 (Witness explains mathematical method of determining the proportion of each of the waters that constitute the reservoir water daily.) By applying that method I can determine the proportion of each of the waters, that constitute the reservoir water daily. They vary from day to day.

1034 As far as analyses enables me to judge there would always be Mississippi river water in the reservoir because it stands in the settling basins for several days and there is a constant mixture there of the two waters.

My analyses show that as we go up the Mississippi river we find the water is badly polluted until we get above the mouth of the Illinois. Above the mouth of the Illinois the Missisisppi is in a very much better condition.

1035 The water of the Mississippi river above the mouth of the Illinois and the water of the Missouri at Bellefontaine they are both fairly good streams from a sanitary standpoint. The nitrites in the Mississippi river above Grafton were lower than the nitrites in the Illinois river above Grafton, and also the nitrites at any subsequent place in the Mississippi river below Grafton, namely, at Alton, and at Hartford, and at the Illinois shore, Chain of Rocks. The nitrites are quite low at the Missouri shore, Chain of Rocks. In the Mississippi river the

nitrites are lower above the mouth of the Illinois and are considerably higher just below the mouth of the Illinois. The nitrites are less in the upper Mississippi river than they are at the intake.

1036 Table No. 14 shows the analyses of the waters on the Illinois shore, at Alton above the sewage of the city and above Hartford above the sewage of the city, for nitrites. (See rec. 1036.)

(For October and November, 1901, same places, see rec. 1040.) These averages show that with very few exceptions the nitrites were higher at Hartford than they were at the Illinois shore, Chain of Rocks, and they were higher at Alton than they were at Hartford. The Mississippi river is more impure above Alton than it is at Hartford, below Alton.

1041 The sewage of Alton apparently has no effect upon the condition of the river at Hartford. Its dilution is so great that it produces very little effect upon the character of the river as a whole. Our analyses shows more nitrites in 1901 than in 1900.

1042 My analyses shows that the nitrites increase as we go up the Illinois river. They are higher in the Illinois river above Grafton than they are in the Mississippi river above Grafton. The Mississippi river above Grafton is in a better condition than it is at the Chain of Rocks. The chemical analyses show that the pollution of the Mississippi comes from the Illinois river.

If it were not for that pollution by the Illinois river, the water of the Mississippi river opposite the intake would be very similar in character to the water on the Missouri side of the Mississippi opposite the intake as to the free ammonias and nitrites. The waters would be almost the same and there would be a higher chlorine found on the Missouri shore than on the Illinois shore for the reason that the Missouri river always contains a larger quantity of chlorine—chlorides, than the Mississippi, but from a sanitary standpoint, the water from the Mississippi river above the mouth of the Illinois, is very similar to

the water of the Missouri river, and were it not for the inflow of the waters of the Illinois river, the Mississippi on both sides of the river at the Chain of Rocks, would be of equal sanitary character. It would be a good drinking water on both sides. As it is now the Illinois comes in and carries with it the nitrogenous organic matter which we find in the river at Grafton and at Alton and at Hartford, and on the Illinois shore at the Chain of Rocks.

1043 The Missouri and Mississippi rivers run through practically the same kind and class of agricultural region and the land in the drainage area of those two rivers for the first 1,000 miles of each stream is practically used for the same purpose by a similar class of people.

Plat No. 12 is intended to show the variation in the quantity of nitrites found in the Illinois river at a point above Grafton, and also at another point above Peoria.

1044 The lower curve gives the average amount of nitrites at a point above Grafton in the Illinois river.

The upper curve gives the amount of nitrites in the Illinois river at a point above Peoria, throughout the time of the analyses extending from January 24 to October 11, 1900.

Offered in evidence as Complainant's Exhibit 33. I made an analysis of the waters of the Illinois river above Grafton.

Comparing the values found for nitrites and also free ammonia, the value found for these substances at Grafton with the same values found at a point above Alton, we find higher values, uniformly above Grafton, than we do at Alton, showing that as we ascend the Illinois river the impurities constantly increase.

We have tabulated the daily analyses of the waters taken at Peoria. We find that at Peoria the amount of pollution was very great and as we go up still further to Joliet and Lockport the analyses showed that the water is simply sewage, and the analyses there for free ammonia and nitrites are such as one obtains by analyzing sewage. Began analyses at Peoria and

Grafton on January 24, 1900. At first we found less nitrites at Peoria than we did at Grafton, in January.

1045 After the opening of the Drainage canal the nitrites at Peoria increased, and were greater in number than those found at Grafton.

I conclude from these analyses that before the opening of the Drainage canal there was sewage matter in the waters of the Illinois river, but there was greater oxidation in the region above Peoria and immediately below Peoria—all along the river there was greater oxidation. That was shown by diminution. That was because it moved more slowly. The rapidity of the current retards oxidation. Before the opening of the canal, the movement was slower and while the water was impure above Peoria, we found a smaller quantity of nitrites there, showing that the oxidation had proceeded further, and then after the opening of the Drainage canal the quantity of nitrites at Peoria increased enormously, and they kept on increasing throughout the time that we made these analyses, and from that I conclude that the effect of the opening of the Drainage canal was to wash these oxidized materials further down the river. The region of bacterial action, and the conversion of nitrogenous organic matter into nitrites was moved much further down the Illinois river and into the Mississippi river below the mouth of the Illinois.

1046 The analyses made in 1901 showed that the same state of affairs existed. The quantities of nitrites found above Peoria were still very considerably greater than the nitrites found in the Illinois river above Grafton.

My analyses showed that the Illinois river above Grafton was more impure in 1901 than in 1900 for the corresponding months.

1048 Comparing the amount of decomposed sewage in the Illinois river at a point above Peoria in January, 1900, with that supposed to be there in the early part of September and October, 1900, I would say it was eight of nine times as

much in September and October as compared with January, 1900. That is shown by the red curve on the chart, which constantly rises throughout that period. The impurities are somewhat diminished as they come down the Illinois river. So far as my analyses go, there has been a decided increase since the opening of the canal in the amount of impurities that come down the Illinois river. In my opinion these impurities are not sufficiently oxidized to be converted into harmless products by the time they reach the Mississippi and the intake tower.

1049 As a chemist and from my chemical examination of these waters, it is my judgment that this pollution and the contamination from the Chicago river continues down through the Chain of Rocks, a portion of it finding its way into the intake tower of the waterworks and thence into the reservoir. In my opinion and from the analyses of these waters, the water supply of St. Louis is contaminated by the Chicago Drainage canal and the sewage emptied into it by the city of Chicago. The volume of water going down the Illinois river is greater since the opening of the canal. The effect of this in disposing of the sewage causes it to be pushed further down the Illinois river and into the Mississippi river in greater quantities than before the opening of the canal. It acts to prevent sedimentation.

The sedimentation would be less now than before the waters of the canal were turned into the Illinois river because there is a more rapid current which carries the suspended matters further down in the stream and gives less opportunity for sedimentation.

1050 The water at the intake is a mixture of Mississippi river and Missouri river water. My chemical analysis discloses that the Missouri river water is far superior to the Mississippi river water opposite the intake. The Missouri river water contains a larger proportion of common salt than the Mississippi river water. I think that affects the flavor of the Missouri river water. It has been found that one of the tributaries of the Missouri river that runs in from Kansas flows over salt beds and this gives it a large proportion of common salt, and that water

mixing with the Missouri gives it a high proportion of
1051 salt. There was a decided increase in the impurities of the water in the reservoir after the opening of the Drainage canal. There was a coincident increase in the impurities of the water of the Mississippi at that time, as shown by all these curves, or nitrites and free ammonia that have been exhibited. In the month of May, 1900, there was a marked improvement in the reservoir water, this improvement being coexistent with an improvement in the Mississippi river water.

I attribute the great improvement of the waters of running streams in spring and summer first to the greater oxidation which takes place in warm weather; secondly, in these waters, to the much greater volume of the streams. Throughout the time of this examination analytical results show that the water on the Illinois shore at the Chain of Rocks was in an unsanitary condition. It was water that would be condemned by water specialists. The figures for nitrites and free ammonia are beyond those that are allowable in a potable water.

1052 In potable water the average or maximum amount of free ammonia allowed is .05—when it goes above that the water is to be regarded with suspicion. If the albuminoid ammonia goes above .2 parts per million, then there is so much organic matter in the water that the conditions are favorable for the growth and development of disease germs. Then, if there are measurable quantities of nitrites, if you can measure the nitrites, that is express the result in numbers, we are usually inclined to condemn such water. If we can at all measure the amonuts of nitrites we condemn the water, as good drinking water has no nitrites in it, and whenever the chlorine goes above the normal amount, that is indicative of sewage pollution.

1055 Witness gives maximum amount of nitrites in water at Joliet in March, 1900, and extending until Oct. 11, 1900.

1056 Witness states the amount of free ammonias at same place and same dates.

1057 Same date for Lockport.

Tables No. 15, 16, 17 and 18 show results above indicated.

1059 Witness states maximum amount of nitrites found at Peoria. Also free ammonia.

1060 Above are read from tables 19 and 20.

Witness gives results of examination for nitrites at Drainage canal, off Pauline street.

1062 Result for chlorines at same place and dates.

1063 Free ammonias, same place and time.

1064 From these analytical results we see that the water of the Illinois river was more highly contaminated with nitrogenous organic matter at Joliet than it was at Peoria and likewise at Lockport there was a greater contamination than at Peoria. Now our results show higher values for free ammonia nitrites at Joliet than they do at Lockport. This I account for by the fact that the samples at Joliet were taken immediately under the Illinois and Michigan canal that passes over the river at that point. The results for Joliet show, or rather the analyses show, that it is sewage. It cannot be called water. The samples we have were really to be called sewage instead of water and at Lockport while the proportions were less than at Joliet, nevertheless we must still call it a somewhat diluted sewage.

1065 Now I notice further that several months after our analyses began along in the spring months, the quantities of nitrites and free ammonia diminished both at Lockport and at Joliet. This is accounted for by the outflow of the water of the Drainage canal. At Lockport the free ammonias diminish from 2.437 down to 1.411 in June. We find that they again increased and in the subsequent year, 1901, they did not diminish below 1.239, showing a partial improvement. In other words, after the opening of the Drainage canal, this concentrated sewage at Lockport and Joliet was diluted. That in portion is the result of the analyses. That before the canal was opened there was concentrated sewage there and that after the canal was opened ther was diluted sewage there and the the results obtained at Peoria and points further down the river show that this sewage from Lockport and Joliet had been washed further down the river. My analyses show that this river was contaminated be-

fore the investigation. The river was polluted with sewage long before the opening of the Drainage canal but after the opening of the canal the sewage was diluted with water and carried farther down. We found at Grafton much higher nitrates and free ammonias after the opening of the canal than before and that in my mind, is evidence of the flushing down of the sewage matter which had accumulated at Lockport and Joliet and in the upper regions of the river, by the opening of the canal.

1066 Plat No. 11 was made by me. It contains curves of the quantities of nitrites in the Mississippi river above Grafton, at the Illinois shore, Chain of Rocks, at Hartford and at Alton and also in the Illinois river above Grafton. Those are the quantities of nitrites that have been read off in the table that have been platted on this chart.

Offered in evidence as Complainant's Exhibit 34. These examinations disclosed that in the Illinois and Mississippi river the water had a decided odor of sewage as here recorded.

Witness describes the various odors of waters in the Illinois river.

1069 The water of the Illinois river above Grafton has a musty smell or a smell of sewage, and that from the Mississippi above Grafton has the odor of earth, earthy or clay like smell.

1072 The chlorines in the Illinois river above Grafton steadily increased. I have here a table giving the average values of chlorine in the Illinois river above Grafton, above Peoria and at Joliet and at Lockport. We see a steady increase of chlorine as we ascend the river to Joliet. The Lockport samples show less chlorine than at Joliet. The explanation I give for that is that the sample at Joliet was taken immediately under the canal, under the Illinois & Michigan canal and probably contained water from that canal.

The nitrites are decidedly higher at a point above Peoria than they are at Grafton. They are lower in the Drainage canal, showing there has been less oxidation, and I think they are a little lower at Lockport than they are at Joliet. That

1073 shows that there is more crude sewage in the canal than there is at points further down. The nitrites being formed gradually, free ammonia is first formed by the decomposing sewage then the oxidation processes set in and gradually form nitrites, so we find more nitrites at Peoria than we do at some of those higher points, at Joliet or Lockport. There hasn't been oxidation sufficient to produce large quantities, but there are larger quantities of free ammonia at the higher points than at the lower points.

This map shows the Illinois river connecting the Drainage canal with the Mississippi river at Grafton; then it shows the Mississippi river below Grafton, at Alton and at Hartford; it shows the flowing in of the Missouri river at Hartford; then it traces the Mississippi river down to St. Louis. The map is an enlargement of the map of the State of Illinois, taking only the Illinois river and the Mississippi river and these rivers. On the side of this map are given the averages of the condition of the water, first before the opening of the canal, viz: in Jan., 1900, at the reservoir. First the table shows the condition of the water at the reservoir in St. Louis in black letters, the amounts
1074 of free ammonia, nitrites and albuminoid in January, 1900, and then below the values obtained for the same substances, in February, 1900, after the opening of the Drainage canal. These are averages taken from the tables we have presented. For instance the free ammonia before the opening of the canal averaged 0.111; after the opening, 0.210. The nitrites averaged before the opening 0.004 and after the opening 0.013. Albuminoid ammonia before the opening was 0.214 and after the opening 0.271. It shows a doubling of the free ammonias and trebling of the nitrites and some increase in the albuminoid ammonias in the waters of the reservoir in February over what there was in January. That was in the reservoir of the St. Louis waterworks. The same table is shown here for the various points on these rivers.

1078 The frequent or sudden changes of nitrites and free am-

monia and chlorides in streams is looked upon as indication of pollution. The sudden changing in the nature of water is always to be regarded as suspicious, because it shows that there is sewage pollution. Sewage brings about changes in the composition of waters much more readily. These fluctuations vary more in samples taken at the same point in a stream charged with sewage pollution than you find in a stream containing vegetable or organic matter. Vegetable organic matter is much more stable than animal matter; that is very much less stable and we are apt to find greater changes and sudden fluctuations in the free ammonias and in the nitrites in sewage polluted waters than water containing vegetable organic

1079 mats. The waters of the Mississippi river above Grafton and the Missouri above the confluence of the Mississippi are much more stable than the water of the Illinois river or of the Mississippi river below the mouth of the Illinois.

Map offered as Complainant's Exhibit No. 35.

1080 CROSS EXAMINATION by Mr. Johns:

Arrived in St. Louis and took up my duties as a chemist September 20, 1899.

Before I commenced these analyses I had not traveled up the Missouri river any to examine the character of the soil

1081 and the locality from which the Missouri waters came. Nor up the Mississippi, nor up the Illinois. I have since traveled up the Mississippi with a view of examining the soil and the water and the sources of the water. Have not traveled up the Illinois, never was at Joliet or Lockport. I have no personal knowledge of the physical situation of the waters and the origin and derivation of the waters of which I have been testifying.

Q. Isn't that knowledge regarded as important in making up a judgment as to the water?

A. Only in so far as the water is of different origin from that which we have examined in this case. A spring with water or a well water it is especially necessary to know the surround-

ings, the country, the soil and the character of the buildings, and so on, with that kind of water but the topography of the country in general through which the Illinois river runs has been described so frequently in reports by various scientific bodies and I have read those descriptions so that I have been able to form a very clear opinion on that point. But I have no personal observation of it whatever.

1083 Describes laboratory in which analyses were made and method pursued.

1087 Unless water is liable to a chemical change if kept any length of time at a different temperature than that at which it was collected.

1088 If kept at a lower temperature than that at which collected would slowly convert nitrites into nitrates and free ammonia into nitrites, but this change would be very much less than if the water had been kept at the original temperature.

The Mississippi river water has considerable matter in suspension. That would settle if allowed to stand. It would vary according to the length of time it is allowed to stand in the reservoir. A glass tube full of water from the intake two feet high, being allowed to stand for four hours, 75 per cent of the solid matter would settle. That would be at least 50 per cent of the original weight of the water.

1090 Have never allowed the water to settle with a view of determining the weight of the matters in suspension. Then there are solids in solution.

1095 There is not a very definite standard of potable water.

1096 The standard of potability for river water is given in our text books something like this: Free ammonia not above .06 parts per million; albuminoid ammonia, if it goes above .18 that shows that the nitrogenous organic matter in that water has approached the danger limit. Nitrites, .001 or .002 parts per million condemns the water because it has gone beyond the limit—measurable quantities of nitrites condemn the water.

1097 If the chlorine runs higher than the average for that section of the country then we suspect sewage contamination. The averages are from 15 to 16 parts of chlorine in the Missouri.

Q. Now then at 23 the waters of the Mississippi become unpotable?

A. No. If it runs very much higher than that we would say it was.

Q. Say it was 50?

A. Yes, we would suspect then sewage contamination.

Q. Now, when you read the figures, I think you read that there were .1112 parts per million of chlorines in the Missouri river off the intake tower at the Chain of Rocks on the Missouri shore.

A. That must be a mistake. There is no such state as that occurring in the Missouri shore. It runs from 10 to 23 parts per million.

1101 In regard to your algebraic formula for determining the relative amounts of two sources of water in a given place at a given time. (Certain algebraic equations are presented to witness.)

Q. Well, if the fact was independent of the algebra that the Illinois river at Grafton at that time was less than one tenth of the Mississippi in volume, your mathematics are not of much account?

A. Well, it shows that as far as the nitrites are concerned, one-fifth of the nitrites were furnished by the Illinois river and four-fifths by the other.

Q. That is precisely to the point I want to bring it. Your algebraic formula does not represent the amounts of water at all?

A. They represent the amounts of water that are necessary to furnish that constituent to the Illinois.

1102 It means that that proportion of the whole, that much of the other water, is required to furnish that much nitrites.

Q. So that it is a calculation of the comparison of pollu-

tion as to a certain element and not a determination of the actual volume of water?

A. It is not an actual determination of the volume of water.

Q. What you meant to attempt to do with that and what you do as far as the mathematical formula is concerned, or algebraic formula, is to determine that if at a given point there are .0120 of free ammonia and at some other point a certain other number of parts and a certain other point a certain other number of parts, these two confluent sources furnish a certain ascertained amount of free ammonia at the given point?

A. Yes, sir. And that is theory and not actual water.

Q. Now, with the waters of the Mississippi and Illinois mixed bearing nitrites into the intake tower and therefore into the reservoir at St. Louis of four parts of nitrites for the Mississippi and one for the Illinois, and supposing at the same time that of the total water going into the intake tower the Missouri furnished three-fourths and the Illinois and Mississippi combined one-fourth, which is your algebraic equation here, that was the conclusion at which you arrived. A. Yes, sir.

CROSS EXAMINATION by Judge Springer:

1103 Q. Now, what proportion of the Illinois nitrites under those proportions got into the intake tower, what amount?

A. Well, if the Illinois furnished one part to the four parts of the Mississippi, which it never does, the Illinois always furnishes more than the Mississippi, but making this assumption one-fourth of the nitrites furnished by the Mississippi would come from the Illinois, and since one-fourth of the nitrites would come from the reservoir, come from that, one-fourth of one-fourth is one-sixteenth, therefore, one-sixteenth of the nitrites in the reservoir would come from the Illinois.

Q. Why do you say that the Illinois never does furnish one part of nitrites to three or four parts of the Mississippi?

A. My analyses show and all the analyses that I have seen

of the water at the mouth of the Illinois and Mississippi, show invariably higher nitrites, especially in the winter time. The Illinois having greater nitrites than the Mississippi.

Q. Certainly, but when one-tenth of the volume comes out of the Illinois of the volume out of the Mississippi to make a total at the Chain of Rocks then the proportion of the nitrites to the whole body is much less for the Illinois than for the Mississippi?

A. Yes, the proportion that came from that, certainly.

GENERAL CROW: Let me understand. You and the witness don't understand each other. You mean the proportion of nitrites in the whole body of water, the combined waters at the intake, that is what you mean? A. Yes, sir.

1104 Result of examination of water of Missouri river at Bellefontaine, for chlorine for the year 1900.

1105 Average same months for nitrites.
Average same months for nitrates.
Average same months for free ammonia.

1106 Average same months for albuminoid ammonia.
Above are monthly averages.

1107 The total solids run very high. The Missouri often is very muddy and taking it unfiltered and simply shaking it up we got an enormous weight of total solids.

I have been informed by the city chemist of the city of St. Louis, Dr. Teichmann, here, that one of the tributaries of the Missouri coming in at Kansas City has gone across salt beds in Kansas, and that it is very highly charged with chlorine, and that is the reason for chlorine in the Missouri river. I never made any analysis of this Kansas river.

Q. Now, if it should appear by analysis that the river from Kansas coming in from Kansas City, which I believe is called the Kaw?

A. Yes, I think that's it.

Q. That if it did not run any higher in chlorine than the waters of the Missouri river above that point, then the theory

as to chlorine constituents coming from Kansas would not obtain?

A. That is so, I agree to that.

1108 In making the analyses to which I have testified here as to the condition of the water at Grafton above the mouth of the Mississippi river, I did not take into account any supposed pollution that might have been brought to the Illinois river by the entering of its tributaries.

If the waters coming into the Illinois river from the Kankakee river above the mouth of that river should contain free ammonia and albuminoid ammonia and nitrites and nitrates in pronounced quantities, they would tend to pollute the Illinois river. And so with the Fox river coming in and the Big Vermilion and other streams known to empty into the Illinois river.

1109 Q. If it should appear upon investigation and reliable data that more than half of the waters constituting the Illinois river at Grafton were contributed by streams entering that river other than the Drainage canal, and that the averages for chlorine, free ammonia, albuminoid ammonia, nitrites and nitrates, were larger or equally as large in the tributaries as in the main river, what would you say or what would be your opinion as to the amount of pollution if any contributed by the stream itself and by its tributaries?

A. In that case the proportion of these impurities which came from the tributaries would form a fraction of the impurity of the Illinois river and the magnitude of that fraction would depend upon the relative volumes of the Illinois and its tributaries and it would vary as the volumes of those tributaries vary.

In my conclusions as to the amount of pollation that is contributed to the Mississippi river at Grafton for the Illinois river, I take no account whatever of what might have come from

the tributaries of the stream. I simply analyze the water as it is taken out of the mouth of the Illinois river.

Q. Then so far as your analysis is concerned, you charged up all the impurities that you found at Grafton to the Drainage canal?

A. Well, in this way, as we ascended the river we found the impurities increasing steadily and I reasoned that if the impurities came slightly from the tributaries of the river the quantities of free ammonia and albuminoid ammonia and nitrites would be pretty constant all the way up the river and up through the tributaries if the waters were homogeneous, they would show that on analysis, but we found as we ascended the Illinois river that there is a very great increase all the way up to Joliet where the analyses showed the water to be diluted sewage.

1110 The water increased in free ammonias and nitrites and in chlorine and in albuminoid ammonia. We determined the chlorine at all points. It wasn't stated in my conclusions. We didn't make a tabulated table of that but on the record or daily analysis the chlorines are given. Chlorine in potable water comes from the salt that is dissolved in the water and there is always a certain quantity present in natural water. Now if we find that a given water has a proportion of chlorine higher than this so-called normal chlorine, we at once suspect sewage contamination, for the reason that common salt is used so extensively in articles of foods and it would thus find its way with the sewage into the water.

In making my various analyses of water to which I have testified the standard of purity for drinking and domestic purposes of river water which I carried in my mind, as to chlorine was as follows: Since my analyses disclose that the Mississippi river averaged in chlorine from 4 to 5 parts per million above Grafton and since below Grafton the chlorine suddenly jumps to 15 and 16 parts per million, I conclude that that may be taken as evidence of contamination as regards chlorine, by the

Illinois river. The safe standard for the Mississippi
1111 should be four or five parts. The Missouri river, however, runs from 15 to 16 parts normally and we cannot use that standard very well with the Missouri. If the chlorine goes higher than 15 or 16 parts then it indicates contamination, but owing to the fact that the Missouri is charged with salt, from the salt beds, we are deprived from using this standard in judging of the purity of the Missouri river. We then fall back upon the nitrites and free ammonias and albuminoid ammonias.

The chlorine at the Illinois shore, Chain of Rocks, runs higher and the averages are higher than the averages for chlorine for the Mississippi river above Grafton. We find, however, that the averages for chlorine in the Illinois shore, Chain of Rocks, are very nearly identical with the averages for chlorine at Hartford, which is above the mouth of the Missouri.

Q. So it depends entirely on where the water comes from as to the potability of the water in reference to chlorine?

A. Yes, in order to use the chlorine standard we have to have the so-called normal chlorine, an idea of what the average of chlorine would be in water in an uncontaminated state. When I gave my opinion as to the potability of water coming from the Missouri at Bellefontaine and the waters coming from the Chain of Rocks, the Illinois shore, I had different standards in mind, as regards the chlorine, but not as regards the free ammonia, nitrites and albuminoid ammonia.

1112 As to nitrites, if you have nitrites that you can measure and readily represent in parts per million, it shows contamination of the water. It is the opinion of a good many writers upon the subject. There are variations, of course. And our own water is not always free from nitrites. We have measurable quantities present most of the time. The work of Prof. Mallet of the Wilmington Board of Health was done a number of years ago and he allows .0135 parts per million, although he states the average for nineteen waters that cause disease was .0403 and Leeds standard for American waters was

.003, that is the allowable amount of nitrites, the maximum amount.

1113 As to nitrates the standard which I use in making my comparisons in regard to the analyses I have made myself and to which I have testified here is five-tenths parts per million. When water comes above that it is to be regarded as suspicious. The standard for free ammonia is that when it gets above .06 it is to be regarded as non drinkable, or rather polluted, that is .06 parts per million. If it contains much higher quantities it may be used as drinking water, but it is dangerous. As to albuminoid ammonia, whenever it gets above three-tenths it is suspicious water and is unsafe.

1114 In regard to solids, I had no fixed amount in my mind as to what was regarded as safe because our solids varied so very much in the Missouri river. In high water it is so heavily charged with mud that the total solids cannot be used in judging of the purity of the water.

Q. Prof. Keiser, Saturday in your testimony you had occasion to refer to a report by Prof. J. H. Long, with reference to analyses made from water taken from the Illinois river in the year 1899, do you remember that? (See rec. 1076.)

Q. You were asked this question, "Give me the result of that, professor?"

"A. The values before the opening of the canal of free ammonia were 0.895 and after opening of the canal 3.060 according to Prof. Long, and according to my analysis 1.950."

That was above Peoria. Now I want to call attention to

1116 the fact that that is the river below Peoria and not above Peoria at the Narrows as you compared it with.

A. Yes, I see that is Wesley. (Wesley is between Peoria and Pekin and after the sewage of the city of Peoria has been received into the Illinois river.) There is no analysis given there above Peoria, that is as near as we could come to it.

Q. Now if you will look at page 64 (of Prof. Long's report) you will see another table, that is the averages for the

summer of 1900 by Prof. Long. Cast your eye along from the Peoria Narrows until you get the free ammonia—what do you find?

A. The free ammonia there in the summer is .21. And at Wesley, 1.62.

Q. You stated the value before the opening of the canal of free ammonia was .0895 and after the opening of the canal 3.060 according to Prof. Long and according to your analysis .0950. You put the comparison after the opening of the canal at 3.060. Now couldn't you have put it Peoria at the Narrows free ammonia 0.21?

A. Well, for the reason that is a further period of time.

1117 The canal was opened in January and we have our analyses that run up to November of the previous year. These first analyses come up to the end of November 1899, and then the next analyses, the nearest analyses that are published, after the opening of the canal at the point nearest Peoria, give the value I have stated in my report. The first analyses by Prof. Long were for 1899 on page 24 I think of this report. That began in July and ran until November 23. It was for the year 1899. Now, beginning with the other table for 1900, it began with June 7th and ran until October 9th. This is the one upon which .021 is based.

Q. That was based upon the analyses of water taken between June 7th and October 9th, 1900, practically the same periods in the two years.

A. Well, one is July and runs until the end of November and the other one begins in June and ends in October. There is considerable difference.

1118 What I want to call your attention to is the fact that in this statement you compare the water at Peoria before the opening of the canal, of the samples taken above the Narrows and after the opening of the canal with the samples taken below the Narrows after the Peoria sewage was in and on that

basis you show a large increase in free ammonias. Isn't that right?

A. There is shown a large increase there, but the analyses come as nearly together as they have been published.

Q. Well, what I want to get into your mind if I can, is the fact that this statement here as to the difference between the conditions before the water was turned in and afterwards, was based upon two very different conditions.

A. Samples were taken at different places, I understand, but they were taken not so far apart in point of time.

Q. Well, there is a great deal of difference between the Illinois river below Peoria and above Peoria.

1121 Q. Your comparisons for this period of the conditions of the waters at the Illinois river at Peoria before the opening and after the opening of the canal, were based before the opening upon the waters above Peoria and after the opening upon the waters at Wesley, below Peoria, isn't that true?

A. I have followed the report as given here so far as Wesley is concerned.

Q. You took it at Wesley then for comparison after the canal was opened?

A. I tried to compare the points as close together as I could get them.

(Same explanation with reference to the nitrites.)

1122 (Same as to albuminoid ammonia.)

1123 Now, having called your attention to the fact that you are basing your estimate upon waters taken at different places, viz: in the first period above Peoria and in the second below Peoria, if it appears from these books that you took your second period at a place below then your conclusions wouldn't be borne out by the fact as it appears here?

A. My conclusion is borne out by the fact that I made the analyses myself of water taken above Peoria and upon those analyses showing an increase of impurities I based the conclu-

sion that there was increased pollution after the opening of the drainage canal.

1124 Peoria Narrows is three miles above Peoria, before the sewage of the city has been received in the Illinois river. This place was called Shady Beach by Dr. Ravold.

Q. I call your attention to your testimony of Saturday in which it is stated, "Albuminoid ammonia before the opening of the canal was 0.572 by Prof. Long; after the opening of the canal, 2.210, by Prof. Long, and according to my analyses, 0.627." Now you have Prof. Long's report before you, please point out in it the page upon which you found the first figure, 0.572. That was in the year 1899.

A. This is on page 36. I took it from the line marked Peoria Narrows, 0.572. The statement from which I took the comparison of the condition after the opening of the canal I found on page 44 where the averages are given for the spring work of 1900. That was 0.221. That was as nearly after the opening as these analyses are given. That was taken from under the head of Wesley, Illinois river. And they my own determinations upon which I base the conclusions gave .627 also an increase over the original for the same period of time.

Q. Now turn to page 64 of Prof.Long's report and on
1125 the left hand column you will find Peoria Narrows, and run along until you come to albuminoid ammonia. What do you find?

A. Well, we find there .34, but I maintain that that is not a fair comparison.

Q. If you took Prof. Long's data for comparison it would show a decrease in free ammonia after the opening of the canal as compared with the period before the opening, taken from Prof. Long's statement?

A. Well, the figures that Prof. Long gives us for the summer months are lower than the figures which he gives us for 1899 for the fall months.

1126 Q. Well, is not that period covered for 1900, between

June 4th and October 1st, according to page. It is the period June 7th to October 7th, Peoria analyses?

A. Yes, sir, that is June 7th to October 9th.

Q. That is the period upon which he bases his comparison for the period after the opening? A. Yes, sir.

Q. Now the same fact will appear in reference to the findings for nitrates, free ammonia and nitrates, would it not, as far as Prof. Long's tables are concerned?

A. Yes, I have used his tables for free ammonia, nitrites and albuminoid ammonia.

Q. Then according to those two tables to which I have called your attention, Prof. Long's tables show a decrease in these items after the opening as compared with before the opening?

A. A very long time after the opening, in the summer months. I didn't know that Wesley was located below Peoria and I didn't know whether the sewage of Peoria got into the river at Wesley, I thought it was considerably below, if anything. I didn't think it was right in the town of Peoria.

1129 Well, what I desire to have you correct, if you desire to do so, is the impression which you left here, that Prof. Long's tables sustain your conclusions as to the increase of these conditions at Peoria, that is nitrites, nitrates and free ammonia and albuminoid ammonia at Peoria before and after the opening of the canal. (No answer.)

1130 Q. Having Prof. Long's tables as appear in his report, to which reference has been made, of analyses of water taken from the Narrows, above Peoria, before the opening of the canal and after the opening of the canal, don't his figures show that there was at that point a decrease in free ammonia, albuminoid ammonia, nitrates and nitrites, in the year 1900 after the opening of the canal, as compared with 1899, before the opening of the canal?

(Witness refuses to answer yes or no.)

1131 Q. In order to direct the witness' mind to the question

that I desire him to answer, I will call his attention to page 36 of Prof. Long's report. Now that contains the averages at Peoria from July 5th to November 23, 1899, is that right.

A. Yes, sir.

Q. Well, now, taking the average found for free ammonia, albuminoid ammonia and nitrites and nitrates at the Narrows, above Peoria, from samples of water taken during that period, namely, from July 5th, 1899, to November 23d, 1899, compare those averages with the averages on page 64 for the summer of 1900, taken at the same place, namely, at the Narrows at Peoria above that city, during the period from June 7th to October 9th, 1900, do they not show that for free ammonia, albuminoid ammonia, nitrites and nitrates, there was a material reduc-

1132 tion in the latter period as compared with the former period?

A. Yes, sir. We are now comparing analyses of waters made at different seasons of the year. We are comparing analyses made in the fall of the year, from July down to the end of November, when the results are apt to be low, with the analyses made in the early summer when the rivers are apt to be swollen with the rainfall, and therefore it is not a good comparison.

In my direct examination I stated that the waters of the Missouri river at Bellefontaine and the Mississippi river above the mouth of the Illinois river are both fairly good streams from a sanitary standpoint.

1133 Q. Are we to understand from that that you regard the waters of the Missouri river as suitable for the water supply of a city?

A. Yes, sir. It is not as good as it might be, but still it can be used. I stated in my direct examination that if there was an ascertainable amount of nitrites in the river water that it was to be regarded with suspicion for potable purposes.

Q. Now in your testimony Saturday you stated Bellefontaine was on the Missouri river 14 miles from the intake of the

St. Louis water works, by river, but it is above the mouth of the Missouri river. You also stated, "In order to get the idea of the condition of the water in the Missouri river during the same period, immediately before and after the opening of the Drainage canal, I have taken the average of the analyses of the Missouri river water from January, 1900, and I find that before the opening of the canal that free ammonia was 0.135, and after the opening the average for February was 0.148. The nitrites before the opening were 0.008, and after the opening 0.014. The albuminoid ammonia before the opening was 0.063, and after the opening 0.395." Now do not these conditions in the Missouri at Fort Bellefontaine show, according to the standard which you laid down this morning, that the waters at that point are not suitable for drinking purposes?

1134 A. During that period of time for which these analyses were made the nitrites ran high and the water was to be looked upon with suspicion, during the summer, however, the nitrites are very low, and sometimes you can measure them, and with that amount I say that the river is a fair stream. It is not as good as we would like to have it, but still, and during the winter months, I admit that it is to be looked upon with suspicion according to the standards that I have given. It ought to be rejected as polluted in its unfiltered state, according to the standards I gave. These conditions prevail usually during the cold season of the year, in November, December, January, February and March, along when the spring rains come the nitrites fall, and in June, July and August, they are low, sometimes we get merely a trace.

Q. Well, what would you say then of a source of water supply for a great city, that four months of the year the water was unfit for use, and they were compelled to take it always from the same place?

A. Well, I should say it ought to be filtered. Boiled anyhow, you can filter it or boil and filter too, and stop sewers from running into it.

1135 The water at the Missouri shore, Chain of Rocks, is very similar with the water at Fort Bellefontaine on the Missouri river. Of course there are variations from day to day, but taking it altogether the water at the Chain of Rocks is substantially Missouri river water.

The intake tower is about 1,500 feet from the Missouri shore.

Q. How far would that tower have to be moved inward in order to put it at a point where it would take Missouri river water only?

A. I asked that same question of the water commissioner, and at the same time asked him why he didn't take the Missouri river water, and he informed me that it was necessary to have the tower out as far as this because in dry weather the river is so low that it is impossible to get enough water for the city without having the tower out at its present position; that at low water, when the rivers got low, there is not enough water any further to the Missouri shore than the present position of the tower.

1136 Q. Then in low water, wouldn't the Missouri river be further from the shore proper?

A. At low water the water falls and the volume in the Missouri is very low, and we get much more Mississippi river water, so that it is necessary to have the tower out at least as far as it is now.

1136 RE-DIRECT EXAMINATION by Attorney General Crow:

1139 The results shown by Prof. Long of analyses made at Peoria are from weekly samples. My samples were daily samples. The daily samples enable you to get a very much better weekly average than simply taking one result. They approach very nearly the continuous condition of the stream. The daily samples are therefore to be regarded as the better for the test as to the purity of the water.

Q. Now, Judge Springer asked you a hypothetical ques-

tion to the effect that if the rivers that run into the Illinois river were highly polluted, if it would not have an effect upon the pollution of that stream, and you said yes. I show you here a book called, "The Illinois State Board of Health." Turn to page 64, examine that and see if it is Prof. Long's report.

A. Yes, sir, it is Prof. Long's report as to the condition
1140 of the Illinois and some of its tributaries. That report is from June to October, 1900. The analyses show that the Illinois river is very much more polluted than any of its tributaries, and at low stages of course, less water would flow in.

1141 I have here a preliminary report to the State Board of Health by Prof. Rauch, M. D., Secretary. There are two appendices, one, chemical investigation of water supply of the Illinois, by Prof. J. H. Long and the other Illinois Basin and its relation to sanitary engineering, by L. E. Cooley, civil engineer. Turning to page 15, I find that Prof. Long, in a note paged to table 7 states:

"From table 7, it will be seen that the amount of organic matter in this water as indicated by albuminoid ammonia and oxygen consumption, is quite large, and as both are undoubtedly chiefly of vegetable origin, its effect should not be lost sight of." This refers to the table giving the physical conditions and constituents of the Kankakee river. I will ask you to examine that table and see if it bears out the statement that Prof. Long makes.

MR. JOHNS: Objected to as not re-examination.

A. Compared with the values for the Illinois river, there is very much smaller free ammonia and albuminoid ammonias. For instance they only run up to .1—free ammonia .1, and the Illinois river running much higher.

Q. I show you here a report of the Illinois State Board of Health: Advance notes of the Sanitary Investigation of the Illinios river and its tributaries, Springfield, Illinois, 1900, with special reference to the effect of sewage of Chicago on the

DesPlaines and Illinois river prior to and after the opening of the Chicago Drainage canal. On page 34 we find a table of averages of chemical constituents of the waters of the canal at Bridgeport, Lockport, Joliet, Wilmington and then Illinois river at Ottawa, Peoria and the different streams that
1142 come into the Illinois. I will ask you to take that, examine it and say if you can determine from that table whether or not the tributaries there are less polluted as shown by the nitrites, free ammonia and nitrates they carry, than that of the Illinois river.

MR. JOHNS: Objected to for same reason.

A. The nitrites run very much lower. The free ammonias are also very much lower than of the Illinois river. This holds for Wilmington, and for Ottawa, on the Fox river, and for Havana on the Spoon river, and for Brownings. The free ammonias and the nitrites, and the chlorines are all very much lower in these tributaries than they are in the Illinois.

If most of the drainage from the tributaries of the Illinois, into the Illinois, were what we would call the rural character that would be different in its effects on the water than if there came into those streams and tributaries sewage flowing through sewers from larger cities and towns. We would find high chlorine, for instance. Now we do find low chlorines in these tributaries that flow into the Illinois, and we also find low ammonia—free ammonia, whereas in the Illinois itself there
1143 is a higher free ammonia, and similarly with the nitrites in the tributaries—they are low. This indicates that the organic matter is of vegetable source when we have low chlorines and low nitrates, whereas when the chlorines are high, and the free ammonia is high and the nitrites high, those three things together indicate animal sewage.

Q. Now, Professor, Mr. Johns asked you the question as to whether or not your analysis made to determine the quantity of Mississippi and Missouri river water that came into the intake of the St. Louis waterworks, was an actual measurement,

scientifically made, of the amount of water of the two respective streams, the Missouri and the Mississippi, that came into the intake of the waterworks at that point, and I will get you to state now, whether or not it was such a scientific measurement.

A. It was a scientific measurement, calculated from the measured quantities of nitrites in the water. It is the usual and ordinary method that water chemists use for the purpose of determining the relative amounts of two streams, whose waters have commingled at a given point. That analysis made by me determined chemically the amount of those waters. It was made for the purpose of tracing these impurities that I found in our reservoir water, to their origin. A chemical analysis of water does not constitute the measurement of the volume of the flow of the water, or body.

1144 The analyses made by me determined the quantity of pollution as contributed by the two streams. The chemist is able to determine that from this method of water analysis.

Q. Suppose where the Missouri and the Mississippi come together the water of the Missouri was about 1-3 greater than that of the Mississippi—but the Mississippi was polluted twice as great as the Missouri at the point of confluence. Then would the amount of pollution found by water analyses below the junction of the streams correspond necessarily with the relative volumes of the two streams at the point of confluence?

A. No, sir. It would show rather than the volume of the streams it would show us the proportion of impurity which came from each of the streams. That is the value of the analytical determination of the commingling waters of the two

1145 streams. I do not consider the water commingling of the Missouri and Mississippi, as it comes into the intake of the St. Louis waterworks, since the opening of the canal, is a safe, sanitary water for the use of cities of this size. The water that I drink at my house is all boiled and filtered.

1147 RE-CROSS EXAMINATION by Judge Springer:

I sometimes drink water when it has been run through a

Pasteur filter. A Pasteur filter would remove the larger proportion of the bacteria from the river water, without boiling, I believe.

Q. Are there any waters in the navigable rivers of the United States that you would recommend people to use without being filtered and boiled, for drinking purposes?

1148 A. Well, I imagine there are some rivers. The upper Missouri is probably in a very good state; and it is navigable I believe for many thousand miles. I believe the Missouri above Kansas City and St. Joseph is a very fair stream and that it could be used as a potable water. I think all of our river waste waters ought to be filtered. There is danger of contamination from any of them unless they are filtered.

WILLIAM C. TEICHMANN, resumed the stand for further direct examination by Attorney General Crow and testified as follows:

States his professional training, and methods pursued in the chemical analyses of the waters under consideration in this hearing.

1154 I suggested to the city authorities that Prof. Keiser be engaged for duplicate work. The work he did corresponded with the work I did, in quantity. I did duplicate work the same as he did. I superintended the analyses of duplicate samples with the samples that Prof. Keiser received in my laboratory.

In order to get the proper weight of the sources of pol-
1163 lution which affect the sanitary character of the Illinois river we will have to consider some figures from responsible authorities on the effect of dilution from the Illinois & Michigan canal and the tributaries.

Since it is of the greatest importance to find out the stages of the river during the periods of drouth, we will look for the low water stages of the Illinois river water shed. Perhaps the lowest on record is that discussed from the U. S. Government data by Lyman E. Cooley in a report published in 1890, entitled

"Lakes and Gulf Waterways as relating to the Chicago Sanitary Problem."

Witness quotes from this work, and adds.

1164 MR. JOHNS: I object to reading from books. If the evidence is competent the books themselves are the best evidence.

From Lyman Cooley's remark we may assume for the purposes of calculation, that the natural low water volume independent of Chicago sewage, above Havana is 300 cubic feet per second and below this point is 8 cubic feet per second. Now this is the condition prior to the opening of the Drainage canal.

1165 From those figures I have calculated the following ratio of dilution of Chicago sewage in the Illinois river prior to the opening of the Drainage canal.

Upper Illinois volume of flow 600 cubic feet per second, as established by Cooley and Harman.

Sewage of Chicago, 400 cubic feet per second, ratio of dilution, 1.05.

Lower Illinois: volume of flow, 1,200 cubic feet per second, that is the upper district runs to Utica and the lower district from Utica to the mouth. That is, the lower Illinois had a volume of flow of 1,200 cubic feet per second and the sewage of Chicago 400 cubic feet per second, making the ratio of dilution one to two. I deducted the sewage from the water.

1166 Now for instance, 600 cubic feet of water I have there and I have 400 cubic feet of sewage, that leaves 20 per cent. 200 to 400 equals 0.5 as the ratio of dilution. In the same way we would refer to the 1,200 cubic feet of volume per second in the lower Illinois and sewage 400. Deduct that 400 from 1,200 and it leaves 800 and 400 is to 800 as is one to two.

Amount of sewage from Chicago was obtained by taking it equal to the water supply of 42,000.00 cubic feet per day. We have thus deducted 400 cubic feet per second as the amount of sewage discharged there prior to the opening of the Drainage canal.

Of course these dilutions are given only to show just what proportion of the Illinois river is made up as the diluted sewage of Chicago and the purification of this sewage must be taken seriously into account before arriving at definite conclusions.

1174 I have no data for my own analytical work of the condition of the Illinois river in 1899, but have consulted the following reports.

Water Supplies of Illinois, published by Rauch.

Long's Chemical Investigations of the Water Supplies of Illinois.

Palmer's Chemical Survey of the Water Supplies of Illinois, etc.

I have here some tables quoted from these reports in their comparison lead to the following deductions, first:

That the Illinois river prior to the opening of the Drainage canal was being constantly polluted by the I. & M. Canal and to such an extent as to give the entire water course the character of a carrier of diluted sewage, showing that the dilution of sewage for the lower Illinois river between Utica and the mouth at times of draught was one to two.

1175 It is true that dilution, sedimentation and oxidation gradually lessen the quantity of characteristic ingredients of sewage present, but not sufficiently by the time the Illinois reaches its mouth to have completed the process of self purification. All the tributaries entering the Illinois river are comparatively much purer than the Illinois itself. That is a conclusion that I draw from these reports.

These are all conditions previous to the opening of the Drainage canal.

The second conclusion that I draw is that there was a remarkable increase in the sewage pollution as evidenced by the higher nitrites, chlorine and free ammonia in the river since Long has examined it in 1888, and again since Palmer's investigation.

This pollution cannot be ascribed to accessions from the tributaries or from the Peoria and Pekin pollution for the reason that during the same period those tributaries show no increase in pollution.

1176 It is only necessary to consider the corresponding increase of water in the Illinois & Michigan canal during this period of 1888, 1896 and 1900 and to remember the enormous growth of population and industries in Chicago to find the right explanation of the gradual conversion of the Illinois river at that time into a condition of very bad pollution.

Prof. Palmer states that "the I. & M. canal and Illinois river were during the fall of 1895 and year of 1896 much more fully charged with sewage than they were in 1888 and 1889," the time of the investigations made by Long under the Board of Health.

As to examinations made prior to opening of canal, from August 23 to January 22, at mouth of Illinois above Grafton and from the Mississippi above Grafton, I have presented a table of maximum, minimum and average results.

(Table No. 1, Teichmann's testimony.)

1178 From the original date it will be seen the nitrites, free ammonia and chlorines of the Illinois river were found to exceed those of the Mississippi.

On September 30, for instance, a sample from the Illinois river contained 31 parts of chlorine per million; 44 parts of ammonia per million, and .015 parts of nitrogen in the form of nitrites.

Whereas in the Mississippi we find, 5 parts of chlorine per million; .134 parts per million of nitrogen in the form of free ammonia; and .002 parts per million of nitrogen in the form of nitrites.

It is true that the highest albuminoid ammonia in the Mississippi river was on the same day found to be higher in the former than in the Illinois river, but it was not accompanied by correspondingly higher nitrites and chlorines. Therefore the conclusion is justified that the sanitary character of the Missis-

sippi river at that time was better than the Illinois river.

1179 We next come to the chemical character of the Mississippi river water between Grafton and the intake of the St. Louis water works in 1899.

There was no doubt of the polluting effect of the Illinois river on the Mississippi.

1180 Analyses of the water of the intake, in 1889. From August 23 to September 16, 1899, four samples were collected near the intake of the water works, but beginning with October 16 and ending January 22, 1900, semi-weekly analyses were made at the intake. The averages of the most important chemical constituents were as follows:

Table of averages, parts per million: Nitrogen as free ammonia, maximum, .138; minimum, .008; average, .0063.

That is the whole of the period at the intake. I will give the number of samples, 26 samples.

Nitrogen as nitrites, maximum, .01; minimum, .0; average, .002.

Nitrogen as nitrates, maximum, .8; minimum, .2; average, .4.

1181 Nitrogen as chlorine, maximum, .27; minimum, .9; average, .17.

The maximum stamps the water as polluted, whereas the minimum characterizes it as good potable drinking water.

These great fluctuations can only be ascribed to the daily varying mixtures of Mississippi and Missouri river waters at the intake which is located on the edge of the channel 1,500 feet from the Missouri shore.

The Missouri river showed much lower nitrites and free ammonias than the Mississippi above the mouth of the Missouri at that time. When the Missouri would go into the intake the impurities in the water at the intake would be low. When the Mississippi river prevailed, the impurities in the intake would go up.

1182 Now as to the final conclusions on the work of 1899, the Illinois river at its mouth was badly polluted during the

entire period. The Mississippi river above the mouth of the Illinois, was much better in sanitary quality than the Illinois throughout the investigation.

The Mississippi river between Grafton and the St. Louis intake showed very much the effects of pollution from the Illinois river and on such days when the Mississippi river water entered the intake, the result would be an increased pollution of our water supply.

The Missouri river was generally purer than the Illinois above Grafton and purer than the Mississippi after its junction with the Illinois river.

The next period of the investigation covers the time from January 23d until October 11, 1900.

Witness states that 3,492 samples were taken and enumerates the various points and the number of samples at each point.

1183 After October 12, weekly samples were collected from the following points until November 30th. (Naming them.)

The sources of pollution in the Illinois river are the sewage of Chicago, the sewage from the towns along the banks of the DesPlaines and Illinois river and from the tributaries. Particularly a large percentage as I have already said, according to the statement of E. O. Jordan, a large percentage of the sewage from Chicago came by way of the I. & M. canal. I wish to emphasize that this is the opinion of Prof. Jordan. Much of the Chicago sewage to-day passes through the main branch of the canal.

1185 The sewage passing or mixing with the lake water in the Chicago river, south branch and entering the Drainage canal, that sewage represents the drainage of a population less than 800,000. That is the sewage that enters the main branch of the canal.

The sewage entering the I. & M. canal, according to my observations and the testimony of Mr. Benezette Williams, comes from the south fork of the south branch.

The sewage that enters the south branch is of a different

character than the sewage in the south fork of the south
1186 branch of the Chicago river. There being no current in the south fork it is kept there for a sufficient time to enable it to undergo preliminary purification. This is not the case with the sewage entering the south branch directly that is draining from the population of 791,677. The south fork may be compared to a septic tank.

Now it has been proven that water when it stagnates facilitates to a great extent, purification much more so than that of running streams. In septic tanks the most effective are always the obligatory anaerobic bacteria. The Chicago Drain-
1188 age canal contains dissolved oxygen. The lake water provides it. There is also dissolved oxygen in the south branch today. The north branch ordinarily is also a septic tank. This is an advantage to the water as it leaves the Drainage canal and enters the Des Plaines and Illinois rivers.
1190 The conduits testified to by Mr. Williams will change this condition and push the sewage right out into the south branch and will prevent its purification while in a stagnant condition in the north branch and south fork of the south branch.

In a measure it is already being done by the so-called Fullerton avenue conduit, whenever that is in operation, but it will be done still more by the Lawrence avenue conduit and the 39th street conduit now in course of construction. This will then carry all the remaining sewage of the city of Chicago through those conduits directly from the Chicago river into the Drainage canal, excepting that part of the sewage, of course, still being dumped into the Illinois and Michigan canal whenever in operation. There will still remain the sewage of the district of Calumet and the district of Evanston, representing in toto a population of about 100,000. They will still drain into Lake Michigan. The remaining sewage will all be discharged into the Drainage canal at the rate of flow fixed by the United States War Department at 250,000 cubic feet per minute.

1193 In all problems dealing with the sewage disposal by

method of discharge of crude sewage in streams, there are two important problems to be considered:

First, the oxidation or mineralization of the organic matter in sewage with subsequent absorption of final products by plant life.

Second, the destruction of pathogenic or disease producing bacteria.

The prime factor which affects the capacity of the streams to accomplish the results as outlined above, are the volume of sewage discharged into it, the degree of dilution of the same, the volume and velocity of the stream, the length of the stream, and finally the character of its water—the chemical and bacteriological character of its water.

1192 The flow of water in the canal is about 1.92 miles per hour in the rock section, and 1.26 miles per hour in the earth.

1193 Taking Prof. Jordan's figures, the ratio of dilution of Chicago sewage in the Drainage canal is one to nine.

These figures should be modified. Less than 800,000 population of the city of Chicago drain directly into the Chicago river, and the south branch and mixes directly with the 250,000 cubic feet of lake water running through the Drainage canal, per minute. Now this sewage, as I said this morning, is running to the Drainage canal, and mixes with the water and is really the only sewage from Chicago, from which a normal calculation should be based as to the ratio of dilution. This ratio of pollution based upon the population of say 800,000 would make a ratio of dilution from one to about twenty-one.

The rest of the sewage from the other 900,000 population drains partly into the north branch of the Chicago river and partly into the south fork of the south branch of the river, and partly, according to the estimates of Engineer Williams, into the lake, the latter representing the drainage of 300,000 into the waters of the lake.

1194 Q. Don't the waters of the north branch of the Chicago river run into the south branch? A. Yes, sir.

Q. And thence into the canal?

A. Whenever storm water and heavy rains flush out the north branch and the south fork much of this sewage which has largely undergone an advanced stage of preliminary purification, is rushed with recent accessions of fresh sewage into the Drainage canal. Eventually it all goes in, but I drew the distinction this morning between the sewage previously decomposed and in the preliminary stage of purification by the anaerobic bacteria and fresh sewages.

I will demonstrate from my data, whenever an increased amount of sewage was run into the Drainage canal during my investigation, the impurities at Lockport would increase. In fact there is shown an increase all along the line up to the mouth of the Illinois.

So that in time of rain, when these streams are high, it all goes in the Drainage canal except the sewage from about 300,000.

1196 ATTORNEY GENERAL HAMLIN: I object to testimony collected from reports and hearsay.

1197 Chemical examination of the water from Lake Michigan in the harbor of Chicago. 32 samples were collected during this period of July 23d to November 17th, 1900, from Lake Michigan, at various distances of from two to ten miles from Chicago.

Since the opening of the Drainage canal the condition of the lake water has improved materially. This is shown by average results of our analyses as compared with those performed by other investigators in previous years.

1198 We found an average of the 32 samples of water collected from July to November, 1900, of free ammonia, .045 parts per million; nitrogen as nitrites, .15; chlorines, .6.

These averages would probably be still lower were it not for the fact that during September on certain days the Chicago river again flowed into the lake because of the temporary closing of the gates at Lockport, and this resulted in a re-pollution of the water on the lake front, and the sample taken near Lake

View crib, December 7th, contained .086 parts per million nitrogen as free ammonia; .014 parts per million, nitrogen as nitrites; .2 parts per million of nitrogen as nitrates; six parts per million of chlorine.

1200 During the last ten years the discharge from the pumps at Bridgeport in the I. & M. canal was practically crude sewage, after having partly been disintegrated by anaerobic action in the Chicago river and in the south fork and north branch.

The analyses of samples of the contents of the canal showed an entire absence of absorption of oxygen, without which practically no oxidation can take place. In other words you have here in the I. & M. canal a septic tank.

1201 These conclusions are largely confirmed by Prof. Long's analyses of 1899, by whom 27 weekly samples were taken between July 1 and November 27, 1899, with the following results:

At Bridgeport nitrites were absent, or present only in immeasurably small quantities or amounts, for all but three of these weeks. Twice they were as high as 01. and once reached .64 parts per millions.

At Lockport almost identically the same conditions were found. The nitrates at Bridgeport were uniform—absent with but one exception. That was before the opening of the Drainage canal.

1203 Results of examination at Joliet, in Des Plaines river: free ammonia, maximum 8.284; minimum 1. 246; average, 2.759.

Rudolph Herring says that when free ammonia is greater than 1.2 per millions, the conditions are probably objec-

1204 tionable. This represents chart 1, describing in curves the comparison between weekly averages of results of analyses of daily samples collected at Lockport, from the Drainage canal, collected at Joliet after mixture of the Drainage canal, and the Des Plaines river, and also respecting the mixture of the Illinois & Michigan canal. The samples were taken

at McDonough street in Joliet and three miles above Peoria. That is the curves will show fluctuations at Lockport and Joliet and that they produce similar fluctuations at Peoria to show that there is little change and practically no material improvement in the Chicago sewage in traveling from the lake front to Lockport.

1205 You see here (indicating on map) a rise in the Drainage canal in free ammonia is followed by a rise of free ammonia in the river at Joliet and is followed by a rise of free ammonia at Peoria, and you will find here the amounts of free ammonia all figured out. Of course the crossing of the DesPlaines river at Joliet by the I. & M. canal—the canal causes a large acquisition of the sewage there from the Illinois & Michigan canal, and that must be taken into account in reviewing this chart. That is what brings those high free ammonias, as I said before, at Joliet, and also brings the high chlorine up there at Joliet, running as high as 32 parts per million of free ammonia; here as high as 54 per million, but you will notice the fluctuations correspond pretty much.

1206 I have a table of average results of daily analyses for the period from January 23 to October 11, 1900, and I have also a table containing the maximum, minimum and average results of analyses from January 23, to October 11, for the same year, 1900.

1207 This would show for the Bear Trap dam free ammonia on September 18, the highest amount of free ammonia was reached at Bear Trap dam, at Lockport, 4.8 parts per million.

Minimum May 18th, .706 parts per millions, making average of 1.585 which is represented on this map here.

Nitrites, maximum also at Bear Trap dam, .2 parts per million; minimum, zero; average, .026.

This is chart No. 2. The red line shows Illinois river; three miles above Grafton. The blue line represents the Illinois river three miles above Peoria.

The curves represent the graphical condition of the Illinois

river at Grafton, and Peoria during January and February, 1900, prior to and immediately after the opening of the Drainage canal, January 17.

These results clearly show the enormous pollution caused by the flushing out of the Chicago river and the Drainage canal, and that owing to the excessive quantities of organic matter present, self-purification was practically impossible. The amounts of free ammonia, chlorine and nitrates represented the effects produced, and although the incomplete purification is also demonstrated by the other results of the organic matter the principal object of this chart is to make a comparison of the results at Peoria and at Grafton during the months of January and February, 1900. It will be noticed that in January, immediately after the opening of the canal, the chlorine go up from 21 parts per million to 28 at Peoria. This is follow-
1208 ed by an increase at Grafton from 15 to 23 parts per millions. It will be seen that the chlorines go pretty much together in the fluctuations at Peoria, as well as Grafton.

As regards free ammonia, we notice the same conditions Illinois river three miles above Grafton as we do three miles above Peoria. The fluctuations correspond between Peoria and Grafton, making allowance for the flow of the water.

This is chart number 3. We find here the results at Grafton and Peoria again campared by covering a period from January until October, 1900.

1209 The top line indicates free ammonias. We again see the corresponding fluctuations in the free ammonias at Grafton and Peoria, particularly during the early parts of the year.

As regards the nitrites, we notice a significant correspondence of the fluctuations in nitrites results for the two points during the first two months, but during the summer months, the warmer weather facilitating the action of the aerobic bacteria in the Illinois river, we find much of those nitrites oxidized eventually because the fluctuations are not so high any more during those summer months for Grafton as they are at Peoria.

Chart number 4 shows the results of the waters analyzed from the mouth of the Illinois several miles above the mouth of the Illinois in the Illinois and several miles above the mouth of the Illinois in the Mississippi. They show above all, the peculiar unstability of the Illinois at Grafton as compared with the Mississippi, a much more stable river as far as its pollution is concerned, and as far as fermentative action itself takes
1210 place.

I have also here the river stages for the two rivers.

1211 My conclusion is that the Illinois river was very much more impure than the Mississippi above the mouth of the Illinois during the year 1900, and was evidently in a badly polluted condition.

1212 I have already stated that the Chicago sewage is only partly purified by the time it reaches Peoria, as was shown on the chart by the high free ammonia, high nitrites and the high chlorines coming together, we must certainly admit a large amount of nitrification and oxidation between Lockport and Peoria, but it is in no sense sufficient to render the Illinois river potable by the time it reaches Peoria.

The water above Peoria, as determined by analytical examinations shows that it is polluted.

I have already quoted Prof. Drown as having stated that high free ammonia, with high nitrites and high chlorines together, establish water as sewage polluted.

Now regarding Peoria sewage. Population of Peoria is 56,000. We figure on 150 gallons of sewage per inhabitant. On this basis we take 8,415,000 or 1, 222,000 cubic feet
1213 of sewage per 24 hours running into the Illinois river from the city of Peoria. That is, if we take the total population. But from recent data I have learned that the sewage draining from the city of Peoria into the Illinois river would represent only 47 per cent of the population. The rest of it goes into privy vaults and is lost in the ground.

Minimum flow of the Illinois river at Peoria prior to opening of Drainage canal, according to Cooley, was 72,000 cubic

feet per minute. If we add to this the discharge from the canal of 250,000 cubic feet per minute, we have a minimum flow of the Illinois at Peoria of 322,000 cubic feet per minute. Now we take the above value of 1,122,000 cubic feet per 24 hours or 779 cubic feet per minute, and we will find that the dilution of the Peoria sewage at a low river stage as was recorded by Government data and presented in Cooley's report, and taking in the whole population, which as I say I have recently discovered is not the case, we find a ratio of dilution of the Peoria sewage in the Illinois river of 1 to 413, at the lowest stage of the river.

In other words, if we take the sewage of Peoria and run it into water at such a ratio of dilution, the sewage would, in my opinion, after a run of from 25 to 50 miles, be sufficiently purified with so much water added to the sewage, so as to remove the effect, the polluting effect of the Peoria sewage on that river.

1214 The sewage of Peoria adds to the pollution of the Illinois river, but only to an extent that if the Illinois river were pure, that would be what I call a comparatively pure water, because absolutely pure water is only distilled water which you find in the laboratory, but I mean to say an ordinary good river water, potable—I will say that if it were a potable water before it came to Peoria, that the sewage entering the Illinois from Peoria would, after running from 25 to 50 miles, purify itself so as to remove the polluting effect of the Peoria sewage on the Illinois river.

Q. You mean by that chemically or bacteriologically?

ATTORNEY GENERAL HAMLIN: Objected to as not being proper; the answer doesn't require any explanation.

A. Chemically, yes.

Q. Do you mean that that would also be bacteriologically purified?

A. Well, that would involve a consideration of the bacterial action of facultative anaerobic bacteria and aero-

1215 bic bacteria.

Q. Well, go ahead.

A. That is, would certainly have finished the purifying process after having run the distance that I have mentioned.

In conclusion I wish to say that the Illinois river as a whole, furnishes a good example of the inability of an excessively polluted stream, excessively polluted at the point where the Des Plaines river enters it, shows the inability of an excessively polluted stream to recover itself.

It is seen that the ability of such a stream to purify itself is dependent on the amount of sewage added, and the volume of water coming down the river, and the results at Grafton plainly show that the Illinois river is at times overloaded with sewage, and literally fails in this capacity of recovering itself or of purifying itself.

Chart number 5 shows:

Sanitary condition of the Mississippi river between Grafton, Illinois and St. Louis.

Red line represents the Illinois river three miles above Grafton.

1216 Blue line represents the Mississippi river one mile above Grafton and yellow line represents the Mississippi river at Hartford and brown line represents the Mississippi river at Alton.

This represents 1900 from January 23d until October 12th.

It will be seen that during the months of January and February there was a marked pollution of the Illinois river water at Grafton.

1217 It is again demonstrated by the results as shown here for nitrites during 1900, that high nitrites at Grafton in the Illinois river were always followed by an increase in nitrites at Alton and Hartford.

That indicates that the Illinois river effectually pollutes the Mississippi after joining it at Grafton.

I have here chart No. 6 showing a comparison of the Missouri river water taken from Bellefontaine, Missouri, and the water taken from the Missouri shore at Chain of Rocks from January 23, to October 12, 1900.

1218 It shows clearly that the water coming down the Mississippi river along the Missouri shore as it passes St. Louis, is principally consisting of Missouri river water. You have here the red line representing the Missouri river at Bellefontaine and the dark line representing the Missouri shore at Chain of Rocks. It will be seen how the chlorines run together, very close together and it will be seen from the total solids that they are almost identical, almost alike.

Whenever the Missouri river is high and is flushed out or storm water comes down the river, there is a marked stirring up of the river and the increased sedimentation produces very high total solids or residue on evaporation. This can be seen if you look at the chart for February and March and April where the amount of solids estimated in parts per million, rose from 800 on February 27 to 3,750 parts per million of total residue was found then in both waters, the waters of the Missouri at Bellefontaine as well as the Missouri river at the Chain of Rocks, and the subsequent remarkable drop back again to about 1,200 in the latter part of March, again shows how closely those waters resemble each other, the waters of the Missouri river at Bellefontaine and the water on the Missouri shore.

Chart No. 8 represents a cross-section of the Chain of Rocks, St. Louis where the intake of the St. Louis water works is located.

1219 This covers from January 23 to October 12, 1900. It shows there are more solids in the water after evaporation, from the Illinois shore than the Missouri shore.

1220 I have a table which I shall present. It shows that the intake tower invariably has higher total solids than the Illinois shore except on the occasion here shown on the map in March when they come very close together, and the Missouri shore has, of course, always higher total solids except on the occasion there where the mixtures result in slightly higher total solids at the intake.

The conclusion is this, that since the results at the intake and the Missouri shore differ as a rule, although they come close

together some times as is shown in August, 1900, that there must be a mixture of the water running along the Illinois shore and of the water running along the Missouri shore, at the intake tower.

1223 In discussing the results of the analyses of samples taken in 1900 from January 23 until October 11, from the Mississippi river between Grafton and the intake, I wish to call attention to the excessive pollution of the Mississippi river during the months of February and March as resulting from the excessive pollution of the Illinois river.

I will just take a week beginning January 30, 1900, and take the averages of the results for this week. The average free ammonia in the Illinois river at Grafton for the week bginning January 30, 1900, the nitrogen in the form of free ammonia found in the Illinois a few miles above Grafton amounted to 1.675 parts per million, while in the Mississippi river, a few miles above the mouth of the Illinois, the corresponding average amounted to .175. That is only one-tenth of the free ammonia was found in the Mississippi above the mouth of the Illinois than was found in the Illinois at Grafton.

At Alton and Hartford we find 1.055 and .865 parts per million respectively, so that we see here from the figures a remarkable increase in free ammonia at Hartford and Alton after the two rivers had mixed.

1224 The Missouri river is noted for its great variations in amount of suspended matter it carries, which variations are most noticeable at the times of freshets, when it may contain as much as 4,000 parts per million of suspended clay and silt.

Another characteristic feature of this water is its high chlorine contents. This is due to the drainage of the Kaw river through large districts in Kansas of salt deposits. The Kaw is a tributary of the Missouri.

A very important point as regards the Missouri is the condition of the banks which owing to enormous corroding action of the current steadily washing many portions of the soil, particularly the case when it approaches its mouth.

1225 The soil that is washed by the freshets into the Missouri river carries an abundance of organic matter contained in this soil, of vegetable origin principally. If the high albumonis ammonias that are found in the Missouri river were due to sewage contamination they would be accompanied by high nitrites and high chlorines. NOW I HAVE DEMONSTRATED THAT HIGH CHLORINES IN THE MISSOURI BETWEEN KANSAS CITY AND ST. LOUIS ARE NOT OF SEWAGE ORIGN, ARE OF SALT DRAINAGE ORIGIN IN KANSAS, BECAUSE THE MISSOURI RIVER ABOVE KANSAS CITY SHOWS COMPARATIVELY LOW CHLORINES.

The nitrites in the Missouri throughout the year are low. They are frequently absent. The fact that they are low and absent and that the variations between the highest nitrites found and at times when they are absent, the variations being very small, show that there is a very little fermentative action going on in the Missouri river, particularly as it approaches its mouth. We are justified in stating that the general character of the Missouri river as it approaches the mouth is one of great stability.

These tables that I refer to show that all the times during this investigation, the second period from January 23 until October 12, 1900, the Missouri river water was better in its sanitary quality than the Mississippi river water at the mouth of the Missouri river. While the averages may show free ammonias quite high in the Missouri river, the averages for the nitrites show much lower results for the Missouri than for the Mississippi at the mouth of the Missouri. That would stamp the Mississippi as being a more polluted stream than the Missouri. And since the chlorines, nitrites and free ammonia in the Mississippi at Hartford and Alton, Hartford being situated one mile above the mouth of the Missouri I say since those results from those points of collection at Alton and Hartford show correspondingly high nitrites, free ammonias and chlorines,

that the pollution of the Mississippi at these points must be principally of sewage origin.

I have here a table of percentage calculations of which I spoke in discussing the charts of the Missouri and Mississippi river water at the intake, a mixture as represented by the analytical results, of total solid determination.

The tables offered are 1, 2, 3, 4 and 5 of Dr. Teichmann's testimony of March 18, 1903. (See rec. 1227.)

1240 Chart number 9 represents a comparison of the per centage of the Mississippi river water pumped at the intake as represented by the determination of total solids or residue on evaporation, from January 23 until October 10, partly and October 30, for the typhoid fever cases.

1241 The percentage of Mississippi river water pumped at the intake during this period as compared with the number of typhoid fever cases for the years representing 1895 until 1899 inclusive.

It will be seen from this chart that during February from February 15 to 25, a marked increase of Mississippi river water in distinction from the percentage of Missouri river water was pumped into the intake. There then followed, taking into account a period of incubation of two to three weeks, a remarkable increase in number of typhoid fever cases reported to the health department of St. Louis.

I also show here in blue the normal number of cases, reported to the health department for 1895, 1896, 1897, 1898 and 1899. They show a very low number of cases during that period and the increase in the number of typhoid fever cases reported in March, 1900, over the period found for the five preceding years amounts to 1,300 percent.

1242 We notice during the latter part of the summer again an increase of percentage of Missouri river water entering the intake and we see subsequently a large increase in the number of typhoid fever cases reported to the health department over the average of the five preceding years. In September, 1900, the increase in the number of typhoid fever cases re-

ported over the period of the five preceding years amounted to nearly 70 per cent.

Chart number ten represents a comparison of the water at the intake, the water after it has been in the reservoir for two days and just before it leaves the reservoir.

Between the reservoir and the tap in the city chemist's office and the intake.

The blue line represents the intake, the yellow line the reservoir and the red line the tap and the top line represents the stage of the Mississippi river at St. Louis and the number of feet are marked up here in lead pencil. They simply show the enormous removal of suspended matter in the subsiding reservoir; the average percentage of removal of suspended matter in the reservoirs for the period of 1900 from January 23 until October 12 represents 85 per cent. That is 85 per cent of the sediment of the water passing through the reservoirs remains in the reservoirs.

Increased pollution of the water entering the intake is always followed by increased pollution of the water in the reservoir. As a rule there is no marked purification as far as the free ammonia is concerned in the reservoir. Whenever the intake water is bad the water leaving the reservoir and the water from the hydrants in St. Louis must be correspondingly affected.

The same applies to nitrites.

Now I wish to call attention to a marked increase in pollution of the water at the intake during the early part of 1900. You will see that there is a tremendous rise in the free ammonia and you will see a tremendous rise in nitrites. The ammonia lines and the nitrite lines indicate this on the map.

1244 There are analyses on record for the last twenty years. None of these ever showed such a remarkable quantity of free ammonia and corresponding with it a large increase in nitrites at the intake tower or the reservoir or the water of the hydrants of St. Louis. At that time (early in 1900) there was a wave of pollution coming down the Des Plaines river, the

Illinois river entering the Mississippi at Grafton running along the Illinois shore opposite the St. Louis waterworks at Chain of Rocks, and as shown by the percentage mixture, entering the intake of the waterworks. We find during that period the percertage of Mississippi river water entering the intake varying from 19 to 100 per cent during this early period of 1900. After the opening of the canal.

1245 Generally comparing the results of the analyses of waters collected between Grafton, Illinois river and the Mississippi river and the St. Louis intake, and also from the Misrousi river and the St. Louis intake, and also from the Missouri river for the periods of 1899 and 1900, we notice from the averages an increase in the nitrites and free ammonia in 1900 as compared with 1899, for the route between Grafton and the St. Louis intake. Our analytical results show that the water entering the intake in 1900 was more polluted than the water entering the intake in 1899, and that the increased pollution, since there was no correspondingly increased pollution in the Mississippi river above the mouth of the Illinois, nor was there increased pollution in the Missouri river above its mouth, it shows that the increased pollution of the water going into the intake tower must be ascribed to the increased pollution of the Illinois river in 1900, and since I have shown that the increased pollution of the Illinois river at Grafton was due to the increased pollution of the DesPlaines river following the opening of the Drainage canal, I feel justified in declaring that the opening of the Drainage canal resulted in increased pollution of our water supply.

1246 After the investigation closed in October, 1900, a number of samples were still collected between October 12 and November 30, from points in the Illinois river, and these samples were promptly analyzed at the city chemist's office. These samples were not collected daily as before.

For the samples taken outside St. Louis they covered the period from October 12 to November 30.

But from October 12 to November 30, 1901, the third period

of investigation, covered in addition to those sporadic samples outside of St. Louis, they covered the analyses of samples collected daily at the Chain of Rocks.

1247 Sample was daily taken during this period at the Chain of Rocks from the Mississippi river close to the Illinois shore. Then a sample close to the Missouri shore. Also from the water right at the entrance of the intake tower, and on from the outlet chamber. And one from the tap in the city chemist's office.

The analytical data thus collected have all been noted down in the report which can be presented if required. They demonstrate the continued polluted character of the St. Louis water supply during this period. Furthermore, that the water along the Illinois shore during this period was at all times more polluted than the water running along the Missouri shore and that during such periods when a mixture of the waters from those two rivers entered the intake, the impurities found in the samples from the intake were higher than those found in the samples from the Missouri shore.

The next or fourth period of investigation, covers the time from October 1, 1901, to November 30, 1901. It was the most comprehensive investigation conducted since the beginning of the analytical survey of these waters in August 1899.

1248 Samples were collected at Bridgeport, Lockport, Bear Trap dam, etc.

1250 First period of investigation was from August 23, 1899, to January 22d, 1900;

Second period, from January 23d until October 12, 1900; and a number of samples were still taken between October 12, until November 30, 1900;

1251 Third period from October 12, 1900, until September 30, 1901;

Fourth period, October 1st came the large investigation and continued until December 1, 1901.

The resumption of the collection and analyses of samples along the water route from Chicago to St. Louis in October and

November, 1901, was undertaken for the chief purpose of ascertaining whether the continued operation of the Chicago Drainage canal during the interval between the cessation of the investigation in October, 1900, and the resumption of the investigation for samples outside of St. Louis, in October, 1900, had produced any improvement of the sanitary conditions of the water as established by the former investigation along this route in 1900. I will now present a number of charts briefly explaining these conditions as we found them.

1255 This is chart number 11 for the investigation of 1901, October and November. This chart represents a comparison of results obtained from the analyses of water in the months of October and November, 1901, from the Illinois and Michigan Canal at Lockport; Des Plaines river at Brandon's bridge, Joliet; Drainage canal, Bear Trap dam, Lockport, and from the Des Plaines river above Bear Trap dam at Lockport.

The red line represents I. & M. canal; blue line the Des Plaines river at Brandon's bridge, Joliet; green line the Drainage canal, Bear Trap dam, Lockport, and yellow line the Des Plaines river above the Drainage canal—that is before they meet.

It will be seen from this chart that during that period the I. & M. canal was highly charged with free ammonia. It reached the figure of 22.4 parts per million of nitrogen in the form of free ammonia. During the last week a considerable fluctuation can be noted and at the time the collection and analyses was started the amount represented the figure of 18.8 parts

1256 per million of nitrogen as free ammonia. The same is true as to the chlorines found in the Illinois & Michigan canal at that time. We see variations there in the chlorine representing parts per million from 106 up to 150.8; then going down again within one week to 120.6, etc.

If we look at the nitrites we find fluctuations in the nitrites but notice that the nitrites do not fluctuate as much as the free ammonia and the chlorines. They are either absent or run up to a maximum of .15. Now that would indicate that the Illinois

& Michigan canal at that time was in a great state of fermentation. The action of the facultative anaerobic bacteria in this canal resulted in a considerable advance in the initial process of purification usually performed by these bacteria.

The variations in chlorine show that the amount of sewage coming into the Illinois & Michigan canal during this time, together with the varying amounts of free ammonia and nitrites, that the amount of sewage pumped into that canal must have been of great variable quantity. The water condition at that time may have been influenced by the action of the anaerobic bacteria somewhat and as it is an established fact that during the colder season of the year the purification process in the rivers is retarded considerably, the results would in a measure explain themselves. We see considerably less free ammonia in the main Drainage canal than we find in the Illinois and Michigan canal. The very high nitrites in the Des Plaines river after the two canal mix with the Des Plaines river at Joliet, show that the process of purification was in an intermediate stage as yet.

1259 Chart number 12 represents or gives a comparison of analytical results obtained from the daily collection of samples of water taken from the Des Plaines river above Bear Trap dam, Des Plaines river at the 9th street bridge, Lockport, and at Brandon's bridge, Joliet. It shows the result of the mixture of the water from the Drainage canal and the Des Plaines river and the result of the mixture of the Des Plaines river, the Drainage canal and the Joliet sewage in the Illinois & Michigan canal. Green line represents Brandon's
1260 bridge, at Joliet; red line Des Plaines river at 9th street bridge, Lockport, the dark line represents the Des Plaines river above Bear Trap dam.

1261 Chart number 13. The curves represent the comparison of the chemical character of the two canals at Bridgeport and at Lockport. Bridgeport is in Chicago on the south fork of the south branch of the Chicago river. Lockport is 29 miles from Bridgeport.

1262 The green color, or this top represents the I. & M. canal at Lockport. The red color or red line represents the I. & M. canal at Bridgeport. What I wanted to show by these curves is the remarkable fluctuations in the amount of free ammonia in that canal, showing its fermentative character. That is in the I. & M. canal as compared with the Drainage canal, the yellow line representing the Drainage canal at Bridgeport and the dark line representing the Drainage canal at Lockport. The ammonias in the Illinois and Michigan canal are very much higher, showing that the anaerobic bacteria have performed their work in the old I. & M. canal much more effectively than in the Drainage canal. The sewage in the Drainage canal as it reaches Lockport does not show very much improvement during its route from Bridgeport to Lockport. It demonstrates that the facultative anaerobic bacteria do not work so effectively in the main Drainage canal as they do in the I. & M. canal. The sewage from the Drainage canal is in a much more retarded state of purification. It is in a much cruder state and it is very much less purified in its initial state of purification at Lockport than the I. & M. canal sewage when it reaches Lockport.

Chart number 14 represents comparison of results of analyses of samples of water collected during the months of October and November, 1901, at Joliet and Peoria, Ill.

1263 The green line represents Des Plaines river at Joliet; the yellow line represents Illinois river at La Salle. The dark line represents the Illinios river three miles above Peoria. The very high results of free ammonia found in the water at Joliet are reduced somewhat by the time the water reaches Peoria. In other words, the initial process of purification has been materially facilitated during the transit of the water in the Illinois river from Joliet to La Salle and Peoria. This map will also show that the nitrites found in the Des Plaines river at Joliet at that time during those two months, were lower than the nitrites found at Peoria and at La Salle. While this would indicate that the process of purification had

advanced somewhat for the sewage running down the Illinois river between those points, the very high nitrites found at La Salle and Peoria—at La Salle representing a maximum of .164 parts per millions and at Peoria a maximum of .154, I say they demonstrate that the process of purification of that sewage in the river coming from the main Drainage canal principally, and from the Illinois and Michigan canal, and from Joliet, that the process of purification has by no means been completed when the water reaches Peoria. The Illinois river, in other words, is found to be highly sewage polluted by the time it reaches Peoria. It is 124 miles between Joliet and Peoria. I wanted to say while the ammonias are much lower at those points of LaSalle and Peoria, they are still quite high and going with comparatively high chlorines and going with very high nitrites, that stamp the water of the Illinois river as it reaches Peoria as badly polluted water, during the entire investigation.

1264 Chart number 15 represents a comparison of results of the chemical analyses of samples collected during this period from October 1, to November 30, 1901, from Illinois river at the points of Beardstown, Peoria, Kingston, Pekin and Grafton. If we take free ammonias here we will notice that with the approach of colder weather the process of purification is retarded in the Illinois river as well as every other river in such climates. This demonstrates that if a wave of polluted water proceeds down the Illinois river, it increases the pollution of the Illinois river correspondingly during its entire course.

1266 Chart number 16 represents a comparison of the results obtained from the analyses of samples taken during the months of October and November, daily from a point in the Mississippi river several miles above the mouth of the Illinois and from the Illinois river several miles from its mouth. The blue line represents Illinois river at Grafton; the red line represents the Mississippi river at Grafton.

You will see that the free ammonias and the chlorines and the nitrites during these two months are always higher in the Illinois river than they are in the Mississippi river at Alton. Until the week beginning the 15th of November there was not much difference between the free ammonias of the two rivers although the free ammonias in the Illinois were always higher, but when the cold weather set in during the latter part of November, the free ammonia in the Illinois river went steadily up, so that finally on the 18th of December it showed one part per million of nitrogen in the form of free ammonia.

1267 Now, there is no corresponding rise to that extent shown in the Mississippi river, while there is an increase there in free ammonias and you can see the effect of the colder weather, yet the Mississippi river must not have been sewage laden to any extent whereas the Illinois river being a river of great instability because as we see, from the nitrites, the intermediate state of purification as represented by the nitrites, is varying continuously. In other words, if the Illinois river were not a heavily sewage laden river, the sewage would have been oxidized much more readily and better, but being in large quantities the effect of the colder weather proportionately retarded the process of purification so much the more and there being evidently considerably less pollution in the Mississippi river the effect of the cold weather there was not so material because of the absence of pollution to any material extent.

1270 Chart number 17 represents the results of the chemical analyses of the samples of water taken daily during the months of October and November, 1901, from a point several miles above the mouth of the Illinois river, represented by red line; the blue line representing a point in the Mississippi river one mile above Alton, the yellow line representing a point in the Mississippi river above Hartford, Illinois, and the green line representing the Mississippi river at Grafton, several miles above the mouth of the Illinois.

The free ammonia for the larger part of this period was lowest in the Mississippi river above the mouth of the Illinois.

It was the highest in the Illinois river several miles
1271 above the mouth of the Illinois and that for most of the time the free ammonia at Alton and Hartford were higher than in the Mississippi river above Grafton, showing that the mixture must have taken place of the Mississippi and Illinois river after their junction resulting in an increase in the free ammonias at Alton and Hartford. That is for the larger part of the period. During one week the free ammonias were a little lower at Alton than they were in the Mississippi river above Grafton. They were also a little lower during the first week in October but only to a very small extent. For the remaining six weeks the free ammonia was higher at Alton than it was in the Mississippi river at Grafton. The highest free ammonia found during this period in the Illinois river was .17; the lowest .06. The highest found in the Mississippi river at Alton was .08 and the lowest is .04. The figures obtained for Hartford were almost like those found at Alton. The variation was slight. The maximum variation amounting to .015 so that I need not quote those figures. I will say the maximum variation showing that the free ammonias at Alton and at Hartford did not vary to any extent.

The chlorines we find lowest for this period in the Mississippi river at Grafton and we find it highest in the Illinois river at Grafton running as high as 26 parts per million. At all times during this period the figures for chlorine at Alton and Hartford were higher than those of the Mississippi river at Grafton and lower than the Illinois river at Grafton, demonstrating that the mixture of the two rivers had taken place in the channel from which the Alton and Hartford samples were collected, and demonstrating further with the increase in free ammonias and chlorines and also a corresponding increase in nitrites, an increased pollution of the Mississippi river from the higher polluted water of the Illinois river.

The nitrites in the Mississippi river above the mouth of the Illinois for this period were very low, as I have already stated for several weeks practically absent. The nitrites in the Illinois river during this period were comparatively high. The nitrites obtained from the Illinois of the samples at Alton and Hartford during this period, always showed an intermediate figure between the always lower figure from the Mississippi river and always higher figure from the Illinois river, clearly demonstrating the mixture of those two rivers and as a result, an increased pollution of the Mississippi river coming from the Illinois river.

1272 Chart number 18 represents results of chemical analyses of samples of water collected in October and November, daily in 1901 from Mississippi river at Hartford and at intake of St. Louis waterworks, Chain of Rocks, and from Missouri river at Fort Bellefontaine. The blue line represents the Mississippi river at Hartford; the green line the intake and the red line the Missouri river. The highest chlorines were found in the Missouri river. The lowest in the Mississippi river at Hartford and the chlorines at the intake represented during the entire period, an intermediate figure. This demonstrates that during this period a mixture of the waters of the Mississippi and Missouri was taking place in the Mississippi river after the junction of the two and its effect could be shown in the lower chlorines at the intake.

Hartford is one mile above the mouth of the Missouri river.

1273 It shows that the free ammonias during the months of October and November at these three points were not differing much. If at this time the nitrites of the Missouri river would be as high as those found in the Mississippi river at Hartford, or higher as was shown by the free ammonia, we could ascribe the higher free ammonia in the Missouri river to sewage pollution, but the nitrites are lower and since the high chlorines in the Missouri river are not attributable to

sewage pollution of the towns and cities on the upper Missouri but are proven to be due to the drainage of the Kaw river through districts of Kansas containing vast areas of salt beds, it is to be concluded that the sanitary character of the Missouri river was better during this period than that of the Mississippi after it was joined by the Illinois river and increasingly polluted by the Illinois river. The figures for the nitrites at the intake tower during this period are almost similar to those of the Missouri river.

1274 Chart number 19 shows the correspondence between the curves representing the chemical examination of the samples of water collected during the months of October and November, daily, in the year 1901, from the Mississippi river at the intake tower at the St. Louis waterworks from the outlet of the St. Louis waterworks for the water as it passes through the reservoir. Now I want to demonstrate by this chart that there is a partial purification taking place in the reservoir. The average amount of sediment that remains in the reservoir is 85 per cent. Now, while the sediment remains in the reservoir to such a large extent the quantities of impurities are not reduced so much—they are reduced some, but it is very small. So small that practically we can say that the amounts of free ammonias and chlorines found in the water at the intakes and the amounts found in the outlet of the reservoir do not differ materially. As regards the nitrites, there is some oxidation taking place in the reservoir at times, but we will see that the nitrites for the month of October do not vary much in the reservoir.

This shows that whenever the impurities rise in quantities in the water from the Mississippi river at the intake, a rise in quantity of these impurities follows in the reservoir and follows in the water taken from the tap of the city water supply. What I said for free ammonia applies also to nitrites as you can see from these curves and it applies to the chlorines and in a measure to the nitrates.

1276 In November and December, 1901, samples were collected from points in the Missouri river about the mouth of the Missouri, at following places. (Witness in each instance gives result of analyses.)

Missouri river, above Omaha, near Nebraska shore.

1277 Ten miles below Omaha at Belle View, Neb.

1278 These results show that the Missouri river, as it approached Omaha, Neb., on November 13 and November 24, was polluted as shown by the presence of free ammonia, nitrites and chlorine. However, the nitrites found on both days being very low, showing only .004 parts per million on November 13 and .001 parts per million on November 24, together with comparatively low free ammonia and chlorine, and demonstrating that the pollution cannot be designated as sewage pollution.

1279 Sample was collected from pump house of city of St. Joseph on the Missouri river on November 14, 1901.

Sample collected 12 miles below St. Joseph.

November 26, sample collected from Missouri river at St. Joseph near waterworks and November 25 at Wathena, Kansas, 12 miles below St. Joseph.

1281 Sample collected on Missouri river, November 17, ten miles below Kansas City.

From Kaw river at Argentine, Kansas.

November 28, sample collected from Missouri river at Kansas City at the point where the waterworks of Kansas City are located.

1282 Ten miles below Kansas City.

Kaw river, at Argentine, Kansas, November 29.

One mile above Jefferson City, November 19, 1901.

1283 November 19, five miles below Jefferson City.

December 1, 1901, above Jefferson City.

December 1, 1901, five miles below Jefferson City.

1284 November 20, 1901, Missouri river one mile above Hermann. Hermann is between Jefferson City and St.

Louis, 125 miles from the mouth of the Missouri.

November 20, three miles below Hermann.

1285 December 1, one mile above Hermann, Mo.

December 1, 1901, three miles below Hermann, Mo.

November 22, half a mile above St. Charles.

November 22, one and one-half miles below St. Charles.

1286 December 3, one-half mile above St. Charles.

December 3, one and one-half miles below St. Charles.

1287 These examinations show with reference to chlorine in the Missouri river that there is an accession of chlorines in the Missouri river at Kansas City from the Kaw, also called the Kansas river, a river which has a length of about 300 miles and drains through a number of counties in which large salt deposits have been located, as it is reported by the U. S. Geological Survey.

The chemical analyses show that the Missouri river as analyzed from Omaha down to St. Louis, has a character of considerable stability. The results are pretty much uniform along the route, with the exception that the high chlorines coming from the Kaw river increase somewhat the amount of chlorine in the Missouri river between Kansas City and St.

1289 Louis. The data on these sheets represents the analytical results obtained from a chemical examination of samples of water collected from various points indicated upon the table which samples were collected and the analyses of the same performed daily during the months of October and November, 1901.

Q. That is enough. The table can be inserted here.

(Table not subsequently furnished F. S. B., Com'r.)

The fifth period of investigation began on December 1, 1901, and continued to July 1, 1902. As already stated yesterday, during this period samples of water were collected above Chain of Rocks from two points only during this period, that is from the Illinois river several miles above the mouth of the Illinois river at Grafton. Daily samples were collected until

December 18, 1901, and daily samples were collected from the Mississippi river a few miles above the mouth of the Illinois river from December 1, to December 14, 1901. With the exception of these samples taken at Grafton from the two
1290 rivers, there were no samples collected from any point during this investigation above the Chain of Rocks, St. Louis, in the Mississippi river.

Five samples were collected daily during this investigation. Three from the Mississippi river at Chain of Rocks opposite St. Louis waterworks—one from Illinois shore, one from entrance to intake tower, one from the Missouri shore, one from outlet chamber of waterworks and fifth sample from tap in city chemist's office, St. Louis.

I have shown in the curves on chart number 16 presented yesterday, the results of the analyses of the samples of water taken from the Illinois and Mississippi river at Grafton from December 1, until December 18.

1293 The investigation, as far as reported to the authorities, terminated on July 1, in the laboratory of the city chemist's office because of the removal of that office to new quarters in the old city hall. After the equipment of the new laboratory in the new city hall, the investigation was resumed on October 1st and continued until January 1, 1903, as follows:

Three samples were collected form Mississippi river at Chain of Rocks, one close to Illinois shore, the other close to Missouri shore and the third one at the intake. Daily samples were also taken during this period from the outlet chamber of the waterworks and from the tap in the new quarters of the city chemist's office.

The results of these analyses do not show any improvement in the sanitary quality of the water supply of St. Louis as compared with the results obtained from the various investigations conducted in the city chemist's office since August 23, 1899.

I consider the Lake Michigan water as it enters the Chicago river, polluted. It is not a pure water. From my examination

of the streams, it is my opinion that the waters of the Drainage canal pollute the Des Plaines river.

1294 The Illinois river is polluted by the Drainage canal indirectly through the Des Plaines river. I can state from my examination of these waters that the water coming into the intake of the St. Louis waterworks is now less wholesome or less pure and less fit for sanitary use and domestic use than it was before the opening of the Drainage canal..

In analyzing water the most accurate results analytically are obtained from samples collected daily.

The English River Pollution Commission was created in 1866 by the British Government for the purpose of investigating the question of the pollution by sewage from cities of the rivers in Great Britain. The investigations cover a period of eight years. During this period six reports were published. It was perhaps the most comprehensive investigation of the kind ever attempted until then and while a variety of opinions have been expressed as to the conclusions to be drawn from these reports, the predominating opinion after the publication

1295 of the reports—

ATTORNEY GENERAL HAMLIN: I object to any opinion given by the English Commission or any statement as to what those reports contain on the ground, first, that the reports would be the best evidence; second, that the evidence is not relative to the issues here.

MR. TODD: The Sanitary District joins in the same objection with the State.

A. The predominating opinion among sanitarians has been that the pollution of streams by sewage from cities and towns located on the banks of these rivers should be prevented by legislation, because the investigations conducted by the commission resulted in establishing the fact that pollution of streams by sewage of towns and cities in England was being carried on to an extent rendering the streams unfit for drinking purposes.

ATTORNEY GENERAL HAMLIN: I move to exclude all of the answer to the last question for the same reasons that are given in the previous objection.

MR. TODD: The Sanitary District joins in the same motion.

In Kansas City, the development of the sewer system did not keep pace with the growth of the population and as a result today only 60 per cent of the sewage of Kansas City goes into the Missouri river. There are as many as 4,000 cess pools in Kansas City into which the sewage of the city is placed and kept there for some time, until the tanks are filled up and the sewage is then disposed of in various ways, used for manuring purposes—some burn it up, and about one-fifteenth of this sewage eventually reaches indirectly the Missouri river, but when it reaches the Missouri river it is sewage far advanced in its purification or rather in its oxidation and has an en-
1296 tirely different character than the fresh sewage run into the river from the sewers. The water of the Missouri river is better for use for domestic purposes and is a more sanitary drinking water than that of the Mississippi river at the confluence of the two streams. The Mississippi river above the mouth of the Illinois river is better for drinking purposes than the Mississippi river above the mouth of the Illinois.

The water coming into the intake tower in January, 1900, and from that time on, as a rule has not been potable. I am familiar with the theories of Tidy and Letherby and other English scientists with reference to the effect of sewage upon running streams. The theory of Tidy and Letherby originally attracted much attention. It practically amounts to this, that sewage diluted in pure water at the ratio of one part of sewage to fifteen parts of water would purify itself after running a distance of about 10 or 12 miles. It was this very theory
1297 that in its application in England proved to be fallacious in many instances, that led to the creation of the

Rivers Pollution Commission in England to which you referred in a previous question. The result of this investigation was that a new theory practically supplanted the theory of Tidy and Letherby in England, and that is that there is no river in England long enough to purify itself. I consider Tidy and Letherby's theory from the facts ascertained by a careful study of the question of river pollution, as antiquated and overthrown by the experiences of many communities in England as well as in other counties. This theory of Tidy and Letherby was tested, so to speak, by investigations carried on in England on the rivers Irwell and Mersey, by Frankland, a prominent chemist and sanitarian of England in the seventies. The conclusions drawn by Frankland from these investigations were that sewage discharged into a river at the ratio of a dilution of 1 to 15, instead of purifying itself after a run of from 10 to 12 miles, only two-thirds of the sewage would purify itself after running a distance of 168 miles.

The Illinois river, after the opening of the Drainage canal, showed its highest stage at Grafton on January 21st, when it showed 5.9 feet. It then began to fall steadily until February 3, when it showed only one foot at Grafton. Then there began a rise steadily from day to day and within a week the stage was 7.3 feet.

1298 It remained close to that figure for the following week.

In the third week in February the river took a sudden rise on the 21st. On the 20th the stage was 6.9 and the following day it was 8.3 and it remained at 8 feet and went up to 8.5 and in the following week began to fall again down to 7.4, 6.1 and at the end of the week was 5 feet.

It rose from the 5th to the 6th of March from 5.1 to 7 feet. From day to day it rose averaging a foot until March 13 it reached 14.8 feet. March 14, 16.1; March 16, 17.3. That was the highest in March and then it fell steadily. For the next month it remained pretty steady around 12 feet.

1299 The Mississippi river at Louisiana, Mo., showed during

the month of January, 1900, throughout, a very low stage varying between 1 and 3. There was a period of very cold weather prevailing at that time and in the beginning of the month in the first week the river was frozen over and again at the end of the month, so that would have to be taken into account in calculating the measurements. Hence, there are such low figures as .7 which means seven tenths of a foot. The stage of three feet was only reached once during that month, on January 19th, for the major part of the month the height of the river varied between one and two and one-half feet. These estimates are based upon the regular gauge of the river as taken for the U. S. Weather Bureau.

1300 In February it was about the same the first week. In the next week it went up to 3.8 and in the following week it showed some slight variation only from 3.4 to 4 feet the highest reached during the month and at the end of the month it fell to 1.5 feet. It remained low again for about a week in March when it rose again to 12 feet on the 15th of March after which it fell steadily until the last week of March when it was 5.1 feet.

1301 The fall in the rivers, the Illinois and Mississippi at those points continued until the 3d day of April when there was a corresponding rise again in both rivers to 8.7 in the Mississippi river and 13.6 in the Illinois river at Grafton, which was the maximum gauge for both rivers during that time. They began to fall down to 5.9 for the Mississippi and 11 feet in the Illinois river during the next week and during the last week of April both rivers rose about one foot reaching a maximum height during that week of 8.4 feet for the Mississippi river and 12.7 for the Illinois river. In other words during this month the heights, the rises and falls in the two rivers were corresponding for the month of April.

Am not acquainted with the waters of the Drainage canal or the Chicago river and its different branches prior to the opening of the Drainage canal in 1900. I had seen these waters

when I was in Chicago. Prior to the opening of the canal, most of the times when I was in Chicago the Chicago river
1302 had the appearance of a dark colored sewer water emitting offensive odors and gas bubbles. The water in the I. & M. canal had the appearance of sewage and it was also of a dark color and emitting offensive odors and gas bubbles.

The Pettenkofer theory of the effect of pollution of waters upon running streams was that sewage discharged into a river and diluted at the rate of one part of sewage to fifteen parts of water would purify itself after a run of fifteen miles, provided that the velocity of the river into which the sewage was being discharged, was at least about the velocity of the sewage and that this velocity was at all times three-fifths of one metre which is equal to about two feet and one inch per second; that would be the least velocity per second.

1303 That theory was advanced first sometime in the seventies. That theory does not maintain today among sanitary scientists in water supplies. One of the greatest difficulties in the country is that running streams in themselves are not pure. The ratio of dilution is based upon a mixture with pure water and whenever the ratio is applied, of a mixture of sewage with polluted waters, it proves to be fallacious. It is true that a number of scientists have declared in various instances and quoted in scientific publications that the theory proved to be successful, but other investigators have shown that those investigations upon which these scientists based their conclusions were carried on in an inaccurate manner. For instance, it was proven that the velocity of the current differs—that is the velocity of the water running along the shore and the velocity of the water running in the channel differ. The velocity on the surface differs from that in the middle depth of the river. The velocity of a channel is greatest in the middle of the depth of the river. Now, in taking samples a great many of these investigators who agree with Pettenkofer evidently have made the mistake of taking samples from

the surface. The character of the water on the surface is different than the character of the water at the middle of
1304 the depth—that is, oxidation processes are somewhat facilitated by light, and the top water in the channel would present a different chemical character accordingly than the water running at a certain depth, as I said before. Therefore Classen, who is a chemist of much distinction in Germany, and water specialist, and others, challenged the correctness and reliability of the analytical results upon which many of the followers of the Pettenkofer theory base their conclusions that Pettenkofer theory was correct. They proved contradictory data showing that this so-called self purification was in reality impossible, etc. These investigations have been published in one of the greatest works that has been written on the pollution of waters, by an investigator of great eminence in Germany.

That is Julius Koenig and the title of the work is "Die
1305 Verunreinigung Der Gewasser," published in 1899.

According to the researches as described in this work a conclusion is justified that the oxidation of sewage discharged in the rivers depends so much upon various conditions and circumstances constantly varying and differing so materially as applied to various streams, that a hard and fast rule as to ratio of dilution cannot be considered reliable any more.

I have a table showing the average daily and weekly rate of flow in cubic feet per minute of the water in the Drainage canal, the I. & M. canal, the Chicago river at Chicago, the Des Plaines river at Riverside, the Des Plaines river at Joliet for the years 1900 and 1901, secured from Mr. Todd, and compiled by L. E. Cooley, assistant engineer of the Sanitary district. In September, 1900, the Drainage canal was closed during the day time for several weeks excepting Sundays. The volume of water running over the dam at night is estimated and represented in the table there. There was some water coming in but in comparison to the regular flow it was a small flow.
1306 The daily closing of the Drainage canal at that time in September, 1900, resulted in the reversion of the flow

of the Chicago river back into the lake and as I have already testified evidently resulted in an increase of the pollution of the water taken from the lake front, and as I also testified, I believe that the Chicago river at that time in the reversion of the flow back to the lake again assumed this character which it had shown prior to the opening of the Drainage canal, that is its color was darkened again and offensive odors and gas bubbles were noticeable along the route of the Chicago river during that period. After the re-opening of the canal with the average regular flow, after that time of temporary closing in September, 1900, the accumulated accretions of Chicago sewage in the Drainage canal being discharged into the Des Plaines river and subsequently into the Illinois river, resulted in increased pollution of these rivers as traced along the route down to the mouth of the Illinois by the analyses of samples collected at points between Chicago and St. Louis at that time.

1307 After having made these examinations I can say that the sewage in the outfalls of the sewers in Chicago goes into the Drainage canal, the Illinois river and into the intake of the St. Louis waterworks.

From these examinations I am able to state that the water of St. Louis is more polluted now by reason of the opening of the Chicago canal and the inflow of the sewage from Chicago than it was prior thereto.

THOMAS A. BUCKLAND, examined by Attorney General Crow:

Am Assistant City Chemist of St. Louis. Have occupied that position for about ten years.

1308 Took part in the examination of the waters under consideration. Worked in the office or laboratory of the city chemist in the city hall. States methods used, etc.

1313 HENRY DETTMER, examined by Attorney General Crow: Am a chemist. Was educated in Germany. In

1314 1900 I was engaged by Dr. Teichmann in this case especially for the purpose of determining the total solids,

and at the present time I am first assistant chemist in our milk examination department in the city chemist's office.

States methods pursued in doing the chemical work and analyzing the samples of water heretofore testified to.

1325 SHERMAN LEAVITT, examined by Attorney General Crow: Am a chemist. States previous experience. Was connected with Dr. Keiser as his assistant for about a year and I worked on this work in the city chemist's office under Dr. Dettmer. I worked on the total solids for Dr. Dettmer.

1326 I was under him. States methods employed and course pursued, etc.

1331 CROSS EXAMINATION by Mr. Johns: Generally the analysis was made the same day samples arrived. We couldn't keep up if extra samples were sent in as they were very often. We would get three or four days behind.

1343 WILLIAM H. GOETZ, examined by Attorney General Crow:

1344 Am civil engineer. Have studied chemistry. I had two years at college and then my experience since. Worked on samples collected for Dr. Teichmann. I performed

1345 the analytical work, and working up the results afterwards, getting them tabulated and averaged in the form of charts. Did all my work in the city chemist's office. States methods pursued.

1364 ALEXANDER N. MILLER, examined by Attorney General Crow: Am a graduate civil engineer, that is I am a graduate in civil engineering. Studied chemistry in connection with my course in civil engineering at the University of Cincinnati from which I graduated in 1897. Have been employed on this investigation by Dr. Teichmann, as analy-

1365 tical chemist. States methods used in the laboratory and also method employed in making sheets showing results of analyses. (Former witnesses also testify to latter fact.)

1372 JOSEPH F. SONDAG, examined by Attorney General

1373 Crow: Am a druggist by trade but since October 1,

1901, I have been employed in the city chemist's office as a clerk. I was assistant at the distillation table and took part in the analyses of the waters brought in from the Mississippi river. I worked under the direction of Dr. Teichmann. States methods pursued, etc.

1377 THOMAS A. BUCKLAND, resumed the stand and was examined by Attorney General Crow.

States what part he took in the analytical work.

1378 I know from my own recollection that I found the ammonias quite high in December, 1901, in the Illinois river at Grafton. The maximum amount I found was somewhere in the neighborhood of one part per million. According to my recollection the ammonias run rather high for the samples taken at the intake during the subsequent months.

CROSS EXAMINATION by Mr. Johns.

1379 I am not prepared to state what caused the ammonia to run high in the Illinois river at that time. I presume it was from pollution in the Illinois river farther up. According to my recollection the state of the ammonias in the Mississippi at that time, was lower—the free ammonia was lower. I do not remember the state of the Mississippi as to ammonia on that same day. Nor of the Missouri. I am not able to state whether the Mississippi was at that time as to ammonia, higher or lower than a fair average. Nor the Missouri.

1380 DR. WILLIAM C. TEICHMANN, resumed the stand for cross examination by Mr. Johns.

Q. What is your idea or reason for calculating the volume of the Illinois river and its flow per minute or cubic feet, or per second of cubic feet, to place it at the extremest low water that you could find data for?

A. The low water stages are the most important in my opinion in calculating the effect of the sewage on the Illinois river, because of the lower volume of water producing a lower ratio of dilution. The idea was to calculate the smallest

1381 amount possible of dilution for the purposes of calculation of the dilution of the river.

A low water stage might continue for a day or a week or ten minutes.

Q. And the very lowest stage is extremely rare and a very unusual thing, is it not?

A. Well, that depends upon the weather conditions very much. But the very lowest stage of the river is the thing which occurs less frequently than an average or a mean stage of the river. I got my figures for the low stage of the Illinois from a report published by Lyman E. Cooley, formerly chief engineer of the Chicago Drainage canal made in the year 1890. I have data as to the stage of the Illinois river from 1890 to 1899. I got those records from reports published by the Illinois State Board of Health up to 1899, in which the stage of the Illinois river was given at various times by Civil Engineer Harman. I did not take some time nearer to the opening of the canal than 1890 as the basis of my data because I thought
1382 that the lowest stage on record would be exactly the stage to take because it might possibly recur again, this lowest stage, and the lower the stage of the river of course the smaller will be the amount of water for dilution of the sewage in the river, and worse than the amounts of pollution shown on the charts.

In your testimony of March 17th, you have the lowest stage at Wilmington, on the Kankakee, 25,200 feet per minute, on the Des Plaines 256 feet and at another time you have for the Des Plaines 339 cubic feet—in the Fox river, 31,339 feet per minute; the Mason river 15,000 cubic feet and the canal at La Salle 37,900—that would make 110,034 cubic feet or 18,339 cubic feet per second. The rivers named are above Utica.

Q. Then where do you get your basis of 600 cubic feet of water, upon which you calculate the basis of dilution and pollution?

1383 Well, Mr. Johns, the question is whether my testimony on that day conveyed that idea. Of course I am not sure about that just now, but certainly the figures that I presented

there would lead to the conclusion that the flow was considerably less than 18,339.

Q. Well, now, how do you happen to assume the sewage of Chicago at 400 cubic feet per second?

A. Well, figuring on the amount of sewage coming from the I. & M. canal, it is simply that the flow per minute is converted into seconds; they would have to take sixty times that; that would give you a certain figure per minute, and that would be the flow from that sewage.

Q. If you have any data or know any way in which you can figure that the sewage of Chicago is 400 cubic feet per second, state now what it is and how you arrive at that conclusion.

A. Well, that was at that time from the Illinois & Michigan canal based on the theory that there is 60 times—figuring on 36,000 per minute of flow.

Q. Assuming that the discharge from the Illinois and Michigan canal was 36,000 per minute, and that 60 per cent of that flow was Lake Michigan water, 40 per cent of it then you say would be sewage?

A. Yes, from Chicago. 40 per cent of 36,000 would be two-fifths—40 per cent would be 14,400. That would be 240 feet per second.

1384 Q. Then where did you get your figures of 400?

A. Well, you must take the total volume of the sewage mixed with the water as it leaves the canal.

Q. That is precisely what I am doing, and assuming that 60 per cent of the flow of 36,000 feet is Lake Michigan water, dilution, and 40 per cent is sewage as you say, then your statement of 400 feet per second for Chicago sewage is incorrect, is it not?

A. No, I don't think so because the sewage as it leaves the canal is supposed to be the sewage mixed with the lake water there. It is diluted sewage; you can't base the calculation on the sewage there, because it is mixed with the water and leaves the canal together; that is what is understood by the sewage

leaving the I. & M. canal. It is of course the sewage mixed with the water there.

Q. Well, you say at the ratio of 40 per cent sewage to 60 per cent Lake Michigan water, so that your assumption of 400 feet was incorrect by 140 feet, was it not?

A. No, sir, not the way I construe it, and the way Mr. Cooley and Mr. Harman construe it in their reports. They calculated on the total volume leaving the canal and entering the Des Plaines river, or rather at La Salle and call it all sewage.

Q. If the flow from the Illinois and Michigan canal is 36,000 feet per minute, and if 40 per cent of that is Chicago sewage; then assuming that state of facts, without any argument with reference to it, your assumption of 400 cubic feet per minute of Chicago sewage is a mistake, it is not?

A. No, I can't admit that, because the mixture there is still sewage.

1385 Assuming that the volume per second of the Illinois river above Utica is over 18,000 feet and that the sewage of Chicago is 400 feet per second, your rate of dilution of 1 to 5 is also incorrect, is it not?

A. Well, based upon your premise.

Q. Assuming that the volume of the Illinois river above Utica before the opening of the Drainage canal was in round numbers 18,000 feet, and that the sewage of Chicago was 400 cubic feet per second, what is the ratio of dilution?

A. One to forty-five. That is a very considerable dilution.

Q. Do you know that in this calculation that you have made here of the stage of the Illinois river above Utica, you have left out a number of rivers?

A. Well, those rivers were left out because in the opinion of Mr. Cooley, their stages were such that they were practically dry during that season of drouth, so that Cooley omitted

1386 them from his calculations. My entire argument upon the question of the dilution of sewage is based upon an

opinion of Mr. Cooley, given in 1890 and also upon an opinion in figuring out those stages and averages, presented by Mr. Harman, published in 1901.

Sewage is the discharge of matter from cities through tubes into some place of exit, including various kinds of discharges. The discharge of sewage in Chicago in 1899, in December would have to be calculated with the water supply. I would make it for Chicago, 42,000,000 cubic feet per day.

1387 I figure that the amount of sewage amounts to the water supply of the city without any kind of deduction. That is an approximation, of course. The figure may not be absolutely correct, but it is an approximation that is accepted by all engineers and practically all text-books on engineering. That's a scientific argument, though that is the basis upon which investigators carry on their investigations, engineers.

Q. By whom, for instance?

A. Well, now, I cannot quote any particular one just now, but it is usually recorded in various text books.

1388 If the water is converted into steam it doesn't return into the sewers, or if it is consumed by animal or man, or if is destroyed in the purposes of some manufactory and its identity lost, it does not again return to the sewer as water.

1389 Assuming that it is 42,000,000 cubic feet per day, that would be 291,666 cubic feet per minute.

Q. Now where did you get your estimation of 400 cubic feet per minute, for the sewage of Chicago.

A. That is the I. & M. canal at that time. The total amount of the sewage of Chicago was not pumped into the canal at that time. Only a part of it. I calculated on 36,000 cubic feet per minute. That was the water pumped at the Bridgeport pumping works.

Adding chlorine to absolutely pure water would be adding impurity to it.

1390 Q. What amount of chlorine in water would make it unpotable to a resident of Missouri?

A. Well, I claim that there may be as much as 500 parts chlorine in that water and yet it may be potable.

Q. If there is any standard, state it, for chlorine in potable water.

A. No standard would be recognized that would condemn water solely on its contents of chlorine. In itself, considered alone, as a constituent in the water, it is the same when you find it whether it comes from dissolving salt or from a dissolving manure heap, chemically, if you leave out of consideration everything else and simply look to the chlorine. It is identified the same way and it is present. Solely as such it is not an element of pollution in water without reference to its source. However, that depends upon what you define as pollution. If entering pure water, it may add impurity to the water, but is generally considered as pollution, I cannot class it with that.

1392 The general definition of pollution in water, is understood to be pollution principally by organic matter and I do not call salts and minerals organic matter, of course. When I find chlorine in water, I cannot tell, considered by itself and separate from all other things, whether it comes from organic matter or mineral matter. Albuminoid ammonia having a number of organic compounds is an element of pollution in water. It is an evidence that in that water there must have been some organic substance. These organic substances may be fecal discharges or the result of dissolution of plants or it may be both. If albuminoid ammonia was to be attributed to the decomposition of fecal matter, it would be the highest in the Mississippi river, in June, July and August. That would apply very well to all rivers and to all waters.

1393 It would be higher in the waters of the Illinois if attributable to vegetable substances, in September, October and November, as a result of the decomposition having taken place during the summer months, of vegetable matter.

Q. When you find albuminoid in water in the Illinois river at Grafton, can you tell whether it comes from decomposition of animal organic matter or vegetable organic matter?

A. In a measure I will be able to distinguish approximately whether this albuminoid may be more of animal origin or vegetable origin, by comparing the results for oxygen
1394 consumed, etc. We take all these things in general together and that enables us in a measure to say approximately and form an opinion as to whether the albuminoid ammonia there may be of animal origin, principally, or of vegetable origin. It is an approximation, but in general we can draw some conclusions from these comparisons.

I found nitrites in the Illinois river at Grafton. I cannot tell whether they are from the decomposition of vegetable or animal organic matter, taken by themselves.

My theory is that the I. & M. canal was in a way a septic tank, and that therefore the waters discharged from it into the Illinois river at Joliet were in a better condition chemically than the waters discharged into it by the drainage canal. I never made any chemical analyses of the waters of the Illinois river at Joliet before the opening of the Drainage canal; I did not have anybody do that. So as to what was the condition of the Illinois river at Joliet consequent upon the discharge of the Chicago river through the I. & M. canal prior to the opening of the Drainage canal I do not pretend to know from my own personal analytical examination.

1395 So that I have no personal knowledge in any way of the conditions chemically either above or below the place where the Drainage canal flows into the DesPlaines river, prior to the opening of the canal as I made no examination of it.

If a septic tank is good at one place it ought to be good at another place in the course of decomposition. Water is only purified to a certain extent in a septic tank—so it would not be benefited by passing through a second septic tank.

1396 It has been established that in these septic tanks the aerobic bacteria are present to a limited degree and these aerobic bacteria by being present in subsequent tanks may to a small degree continue these processes of purification and produce a purified product, that is, as far as they are able to do so

in that tank. In the I. & M. canal there was some current of water. The current is exceedingly slow and it depends very much upon the amount of sewage pumped into the canal and how long it is permitted to be in the canal. It varies greatly. If 36,000 cubic feet per minute were pumped in and 36,000 cubic feet per minute discharged there was a current in the I. & M. canal at that time. If that was the average state and condition, it must have had somewhat of a current.

If below where the I. & M. canal discharged into the Illinois river there was a stretch of river of say three miles, in which the current was very slow, scarcely perceptible, that would operate as a septic tank.

1397 If there was another stretch of 23 miles that would also operate as a septic tank. In any investigation of the Illinois river that I have made, a long and continued series of septic tanks would have been very beneficial to the purification, in a measure. I know that upon the Illinois river there are a large number of bayous and lakes, adjoining the banks of the Illinois river, which are spring fed and which in low water discharge their water into the Illinois river and which in high water are completely overflowed. They could operate as septic tanks. From my own personal study I don't know whether they do or not.

In the course of the investigation we took cross sections of the Illinois river. We took some at Joliet and then at points below Peoria and Pekin. We took one at Kingston, Illinois, which is eight miles below Pekin.

1398 The cross sections taken at Pekin and Peoria represented three sections across the river—we took the center of the river and then the right and left shore. I have not as yet presented the result of the analyses of these cross-sections. The average stages of the Missouri, Mississippi and Illinois

1399 rivers from August, 1899 to January 22, 1900, were comparatively low. (Table No. 1.) This is the table of the data for 1899, compared with the Illinois and Mississippi rivers at Grafton.

1399 MR. JOHNS: We would like to have the table presented showing the results of the analyses of each sample at that place at this time. We don't understand that table has ever been given.

1400 I don't recollect just now how many samples we took from September 6, 1899 to January 17, 1900. There were 18 samples taken.

1402 I got the information that only 47 per cent of the population of Peoria discharged its sewage into the Illinois river from a report published by Mr. Harman, civil engineer, in the Illinois State Board of Health report of 1900.

1403 I don't know that by any personal examination. I know that at Peoria there are a number of large distilleries and very large glucose works and that there are a great many other manufactories in the city of Peoria. I know that in these distilleries a very large number of cattle are fed and that the sewage from this city of Peoria, in proportion to its population is enormously large. I won't admit that it is very much disproportioned to the amount of the water supply as discharged from its sewers into the river. I know that quite an amount of sewage and refuse matter is dumped into the Illinois river at Peoria, between Peoria and Pekin. I do not admit it is disproportionate to its population.

1404 Q. Did you ever see floating down the Illinois river islands of discharged animal matter, combined with straw, and find them sixteen and eighteen miles below Pekin, 25 or 30 miles below Peoria?

A. I haven't seen such, but I have heard of so-called floating islands coming down the river there and being recognized by parties in the towns below Peoria, between Peoria and Beardstown.

Q. Now, that is a very unusual state of affairs, isn't it?

A. I have seen some of these so called little islands myself. I remember now, in the trips I made down that river on such occasions.

1405 Q. If the sewage of Peoria will purify itself, if the dilution which it receives from the Illinois river, in a run of from 25 to 50 miles down the river, why will not the sewage of Chicago discharged at Lockport, purify itself in a run from Lockport to Peoria?

A. First of all, the sewage of Peoria cannot purify itself by such a run of from 25 to 30 miles under the conditions prevailing in the Illinois river. That is, the water of the Illinois river as it reaches Peoria not being sufficiently pure. The water in the Illinois river as it reaches Peoria and passes down is confined to the current in the Illinois river. There is water outside of the current, but it is the current of the Illinois river that carries the water of the Illinois river down that river. There is a different speed of the river in the channel from the speed along the shore.

1406 The sewage as it enters the Illinois river from the sewers does not reach the channel right away. It remains along the shore and since it has been established that the velocity of the river along the shore is always slower and different from the channel itself and there being quite a number of impediments there, the river makes certain curves between Peoria and Pekin, there is a considerable slackening of the speed of the river along the shore and this sewage from Peoria has a considerable time to perform certain initial purification processes along its route whereas in the channel the current is faster and this sewage from Peoria when it reaches the channel finally has remained for some time along the shore and has undergone certain processes of initial purification. The chemical analyses of cross-sections show that. In a measure we can call that a septic tank.

Q. Now, if the waters of the Illinois river were potable when the sewage of Peoria was deposited in them, and if the waters of the Illinois river were of the same volume as they are now with the drainage canal open, would the sewage of Peoria purify itself in 25 or 30 or 50 miles?

1407 A. If that water, the Illinois river water, as it reached Peoria, would be pure, from the analytical data obtained, from the examination of samples of water collected between Peoria and Grafton, the conditions as described by me prevailing in the Illinois river, between Peoria and Kingston, and through the lower towns there, these analytical data would demonstrate that chemically the effect of the pollution of the Illinois river by the Peoria sewage would not be noticeable. I previously said it would take from 25 to 50 miles for that sewage to disappear in the channel of the river, not to be noticeable in the channel of the river, the effect of it.

MR. JOHNS: You are to assume that the waters of the Illinois river at Peoria are potable, and of the same volume as when the Drainage canal waters flowed at that point, and at that point they receive the sewage of Peoria, would not those waters purify themselves so as to be again potable in a run of 25 or 50 miles, and I would like you to answer yes or no.

A. Whether that sewage would be purified or not, absolutely purified or not, that is a question I cannot answer, because, as I said, the water in the channel shows a different character from the water along the shore, and samples taken from the channel from 25 to 50 miles below Peoria do not show any more, chemically, the effect of the discharge of sewage of Peoria into the river. That don't preclude that the Peoria sewage may still be, partly, in a partly decomposed state along the shore, not in the channel, and may still necessitate fur-
1408 ther purification before it could have disappeared, from the anayltical results.

(Question repeated.) A. As I have stated before, a chemical analysis of the water taken from the channel 25 to 50 miles below, would not show any more the presence of the sewage from the city of Peoria, but that would not preclude the sewage from the city of Peoria still being in the river along the shore, undergoing its natural processes of gradual purification.

1409 Assuming that the waters of the Illinois river when they

reach Peoria, are potable, and of the same volume as when the Illinois Drainage canal is discharged into them, and that at that point they receive the sewage of Peoria, would these waters become potable again in a run of from 25 to 50 miles?

A. I don't think they would; that is, potable in general.

Q. Would they become potable in a run of 75 miles under the same circumstances supposed in the previous question?

A. That would depend very much upon the character of the sewage of the city of Peoria.

Q. You made a statement on March 17th, that the sewage entering the Illinois river from the city of Peoria, after running from 25 to 50 miles, would purify itself so as to remove the polluting effect of Peoria sewage on the Illinois river? (See rec. 1214.)

A. I said chemically, yes. I didn't say at that time, but it was understood, and if I had been asked the question I would have said so at that time, that a chemical examination of the samples of water taken at a point below Peoria, and taking into consideration the general conditions of the river, I would say that that sewage disappears from the channel, that is, the chemical result would not show its presence in the channel.

1410

Q. 25 to 50 miles below Peoria, do you think it would show its presence along the sides of the channel?

A. The cross-sections that we have taken from the Illinois river below Peoria show chemically a difference between the water running along the shore and running in the channel.

Q. Does it show in the Illinois river on the sides, or would it show, and not in the channel, 25 to 50 miles below Peoria?

A. That I couldn't tell because I haven't made any examination of samples from that point. I have not produced any analyses of the cross-sections which show any such results here.

The samples of water which I took from the Illinois river were all taken within the channel. The orders issued to the collectors were that they should always take them from the chan-

nel. When I took samples at the Chain of Rocks, on the Missouri shore the sample was taken as close to the Missouri shore as was necessary to get a characteristic sample of the Missouri river water as it hugged the Missouri shore.

That part of the river which runs close to the Missouri shore is composed principally of Missouri river water.

Q. Run a line two miles up the current of the Missouri river and a line in the current of the Mississippi river at the junction of the two, and what would the angle be?

1412 A. That would produce an angle.

Q. Produce pretty close to a right angle, wouldn't it?

A. Yes, sir.

Q. Well, when there are equal stages of water, and in an average condition, your theory is that the current of the Mississippi overcomes the current of the Missouri and turns it down the Missouri shore towards St. Louis.

A. No, not exactly; it doi.'t turn it over to the shore so that the Mississippi river would prevail. The two currents will run alongside of each other, each river hugging one shore —the Missouri hugging the Missouri shore, and the Mississippi river hugging the Illinois shore. Now, it will depend entirely upon the volume of water in each of those currents which will prevail in the channel—of the channel water.

Q. When the stages of the river are equal, the fact is that the current of the Mississippi overcomes the current of the Missouri and turns it down at right angles, and runs it along the Missouri shore?

A. Yes, that can happen. It does hapen.

Q. But at the same time there is more or less a mixture of each of the rivers on the Missouri shore at St. Louis, at the Chain of Rocks?

A. Sometimes this mixture which may be found in the channel may crowd over toward the Missouri shore somewhat, but still our analytical data show that samples taken close to the Missouri shore will always be prevailing Missouri river water, if close to the Missouri shore.

1413 Before the Mississippi and Illinois meet there is a long narrow strip of land that divides them, and when they meet they run almost parallel; that is, they come together slowly. The Illinois river water keeps close to the Illinois shore. It is entirely a different situation than that at the mouth of the Missouri. The place where the samples were taken at the Chain of Rocks was left very much to the judgment of the collector.

Q. There was then, as to the Missouri shore, no fixed and certain place at which the samples was taken?

A. No, sir, it depended upon the current entirely and it was left to the judgment of the man who took the sample as to where he should take it.

1414 Q. So that a sample one day might have been taken 300 feet from the Missouri bank, and the next day 1,000 feet from the Missouri bank?

A. Yes, sir, if the current would run that way; he was instructed to get samples accordingly. The current of the Missouri at the Chain of Rocks on the Missouri shore is constant and regular. It varies somewhat in volume and in the width of the current at that place, but there is always

1415 some Missouri river current water running close to the Missouri shore. Our analytical data shows that. I could not tell from the analytical data alone whether a sample was taken within three hundred feet of the Missouri shore line or whether it was taken from about nine hundred feet from the Missouri shore line.

1417 Q. Do you suppose that any of the water which you took at the place which is designated as the Illinois shore ever got into the intake?

A. Yes, it got into the intake quite frequently.

Q. Well, how did it do it?

A. Well, when the Missouri river was low, and the larger volume of the Mississippi river water coming down the Illinois shore would push the Missouri river toward the Missouri shore and beyond the intake, which is 1,500 feet distant from the

Missouri shore line, and on such days the Mississippi and Illinois mixture water would get into the intake.

Q. Now let us see if we can understand each other. The point on the Illinois shore opposite the Chain of Rocks, and the point at the intake tower and the point which you designate as the Missouri shore, constituted a cross-section of the Mississippi river?

A. They were to constitute a cross-section as near as possible.

1419 Q. The water at the Illinois shore at the point at the Chain of Rocks, and at the point from which you took it, never did get into the intake, did it?

A. It could not on such days because the point of collection was to be far enough away from the intake so that it should not be water that was going into the intake, but should be water that was passing along the Illinois shore.

1421 Q. Take your chart 8, for instance, and tell me whether or not you base your calculation as to the percent of chlorine at the intake tower upon the 23d day of January upon the data which that table or chart shows?

A. Yes, based upon the chlorines there I made an approximate estimate there, and an approximate average of the percentages as found at the Missouri shore, Illinois shore and the intake tower, at the Chain of Rocks.

1422 The waters at the point called the Illinois shore do not turn a right angle and make a straight shoot for the intake tower.

Q. What point up the Mississippi river do you think that it would be fair to select in order to get a sample of Mississippi river water which actually intermingled with the Missouri and went into the intake tower?

A. I consider one mile above the mouth of the Missouri river in the Mississippi as a proper point.

Q. Well, then your calculations as to the pollution of the waters of St. Louis having been based entirely on the samples

taken at the Illinois shore, are upon a false basis, are they not?

1423 A. I cannot say that they are on a false basis because they have not been compared in such a way.

Q. Where did you obtain data upon which you base the calculation made as to the percentage of Mississippi river water and Missouri river water entering the intake tower?

A. One sample was taken from the Missouri river at Ft. Bellefontaine; another sample from the Mississippi river one mile above the mouth of the Missouri designated as Hartford in the analytical records; the third sample was taken from the collection point at the intake tower. The samples from these three points were compared. The residue on evaporation was selected as affording the widest range in figures, and therefore the closest approximate estimate of percentages of mixtures at the intake.

Q. What percent of what proportion of the water taken at Hartford of the entire water, was Illinois river water at that point you don't pretend to know?

1424 A. Well, by inspection alone I could not ascertain that chemically that water was a mixture, it required the chemical analysis subsequently made to determine that Illinois river water was contained in the mixture running in the channel.

1428 If I find by analysis that the water going into the intake tower has a higher per cent of pollution than the water of the Missouri river at Bellefontaine, my chemical conclusion is that the water going into the intake tower is very largely Mississippi river water. My conclusion is based not upon any ability to observe by the currents, which river it is, but solely and entirely from the chemical analysis.

1429 Q. Why, in order to determine the respective quantities of Missouri and Mississippi river water pumped, did you take a sample from the Illinois shore when you knew it was a physical impossibility for that water to be pumped at all?

A. Well, that is to show the character of the current

running down the Mississippi river at the Chain of Rocks.

1431 Q. Was chart 8 made for the purpose of showing that the water at the intake tower was intermediate in its quality, as between the Missouri river and the water on the Illinois shore?

A. In so far that the study of the analytical data proved that, yes.

As to chart 9, my data as to typhoid wer obtained from the Health Commissioner's office of St. Louis. My instructions were to take them from the official reports.

1433 Can you explain why the typhoid fever in St. Louis did not visibly increase from March 20 to August 14, 1900?

A. In February, the upper Mississippi above the mouth of the Illinois was low. The water then represented in the mixture at the intake—I want to say that evidently there was a larger percentage of Illinois river water, of that mixture going into the intake in February and being represented by a high percentage, one day as high as 100 per cent, going down again and then going up again, in February, up to 90 per cent; there was more Illinois river in that mixture; that was followed by a rise in typhoid for the month of March.

Q. Now, why did the typhoid fall and the percentage of cases fall when the Mississippi river was at 100 per cent on the 27th or in the middle of April?

1434 A. Because then at that time the Mississippi river water had a different character than the Mississippi river water coming down in February, and it had a larger per centage of upper Mississippi river water and a smaller per centage of Illinois river water.

Q. So that the chart doesn't contain anything about the Illinois river, but simply assumes that when the typhoid fever is bad, the Illinois river water prevails.

1435 I have ascertained that a large majority of the cases of typhoid fever in St. Louis reported during one year after the opening of the canal, that these cases all correspond

with the fact that the patient had been drinking city water during that period. I got this from the official reports of the physicians when they reported their cases to the health department.

1436 These reports show that in some instances they have been drinking milk. There are about 3,500 or 4,000 wells in St. Louis. There are quite a number of cisterns in addition to that, so that we usually say there are 7,000 cisterns and wells in the city of St. Louis. It was ascertained in this special investigation that of the 1,160 or 1,180 cases reported in 1900, of typhoid, three-fourths of these patients did not drink any well water or cistern water, but only drank water from the city supply.

CROSS-EXAMINATION by Mr. Todd: These 1,180 cases were cases reported by the physicians of St. Louis to the Health Department—not deaths. The number of deaths in 1900 was over 100.

1438 There has been typhoid fever in the city all along every year—the statistics will show some typhoid.

1439 Have been connected with the Board of Health of St. Louis for ten years. There was a letter sent out to the physicians in the city asking them to report typhoid cases coming under their immediate care in the fall of 1900 and another one issued in the fall of 1901.

Q. Previous to the one issued in the fall of 1900, do you know of any letter having been sent out to the physicians in St. Louis during your term in connection with the Health Department of the city of St. Louis?

A. There wasn't exactly a letter sent out, but I remember as long as I have been connected with the health department that the Health Commissioner has frequently requested physicians through the press and in official reports, to report the number of typhoid more promptly.

1440 Q. Well, that letter stimulated the doctors in reporting cases of typhoid, didn't it?

A. Well, it called their attention to the violation of that law in not reporting cases.

1442 There were more cases of typhoid in 1899 than 500; that is during the entire year. Typhoid was very low, but during one month they went up some.

That increase in typhoid was in November, 1899.

1443 Q. The Drainage canal had not been opened then?

A. That I couldn't tell.

1445 I do not consider myself a medical expert on typhoid.

Q. Can you as an expert in chemistry attribute any part of the 1,180 cases in 1900, to the opening of the Drainage canal?

A. Indirectly, yes; in connection with my statements. I consider it in a measure as very striking that with the increase in the pollution of our water supply, and the increased pollution of the DesPlaines river from the Drainage canal, and the Illinois river and the Mississippi down to the intake in the year 1900, I consider it very striking that there was corresponding with that increase in pollution in the month of March, 1900, an increase in typhoid of 1,300 per cent over the average of the five preceding years for the number of cases in St. Louis.

1446 A person not a chemist nor an expert on typhoid could draw the same conclusions if he would give the matter as careful study as I have tried to do. During the five years previous to 1900, the water supply of St. Louis as found in the hydrants, was not good, potable water. It required boiling, and filtration.

Q. Now, do you compare potable water or drinking water as being bad or worse?

A. I do compare the analytical results in 1899, prior to the opening of the canal. I compare those results with those of 1900, 1901 and 1902, after the opening of the canal, and the water has become worse in its chemical character since the opening of the Drainage canal.

1447 Q. But before that it wasn't drinkable, was it?

A. Frequent warnings were issued by the Health De-

partment and myself to boil the water or filter it well before drinking. Those instructions were given because the water was not found to be potable. The water as it existed today, if filtered or boiled would be as good as the water that existed prior to 1900 if boiled or filtered. The Health Department of St. Louis has advised the citizens not to drink the water of St. Louis since 1893.

The water as proved to be prior to the opening of the Drainage canal, was polluted. The analytical results showed pollution in a measure from sewage and in a measure of vegetable origin.

Q. Where did the sewage come from that got into the water of St. Louis?

A. In my opinion, as a result of my investigation in 1899, I found that the Missouri river and the Mississippi river above the mouth of the Illinois were of much better sanitary quality than the Illinois river at the mouth of the Illinois, and I found at that time that the Illinois river polluted the Mississippi river after meeting the Mississippi river and that this pollution extended along the line or along the route of the Mississippi river as it came down and passed the intake, or at times when the Missouri river was low, it would go into the intake. At that time the Missouri river water was potable.

1448 Missouri river water is now potable water. In this case I testified as a chemical expert who is supposed to make himself familiar with all the bacteriological features connected with the chemistry of water. Chemically, I am prepared to say the waters of the Missouri are potable. But bacteriologically, I am not prepared to answer the question. The water

1449 of the Mississippi river above the mouth of the Missouri was not potable prior to the opening of the drainage canal.

1450 I am prepared to say that (prior to the opening of the canal) 75 per cent of the daily quantity of water going

into the intake would be Missouri river water, and about 25 per cent would be Mississippi river water.

Q. Would the amount of Mississippi water entering the intake be sufficient to keep the water supply of St. Louis in a polluted condition?

1451 A. As I stated in my testimony in direct examination, prior to January, 1900, the water supply of St. Louis as coming from the water going into the intake, was potable at times. I said in my conclusions there were great variations, and at some times the water would be a good drinkable water, the water would be potable, and at other times it would be very bad, polluted, as I said. (Witness states on page 1447 that the water was not potable.)

1452 Above Grafton, the water of the Mississippi river prior to 1900 was potable.

1453 The Illinois is prevailingly a slow river, sluggish current. Its current is supposed to be slower than the Missouri and Mississippi and the results of examinations as published demonstrate that. The volume of water coming down the Illinois varies greatly. Sometimes may amount to 1,200 cubic feet per second and then it may be 112,000 cubic feet per second. The volume of the Mississippi never goes down to 1,200 cubic feet per second from what I have studied about it.

1454 The Illinois river water, as it runs along the Illinois shore, is stopped by dikes, and it is kept in the corners of the dikes, and only a part of that water is gradually, when the upper rivers rise, swept out, and gets into that narrow channel, so that the identity of the Illinois river, as such, would, in my opinion, be lost before it reaches the intake.

1457 Took samples from DesPlaines river in October and November, 1901. From the analyses made of those samples I considered that water potable water.

1458 I mean by that good drinking water. I know that some towns drain their sewers into that river. I do not know that the waters of the DesPlaines river have been condemned by the Board of Health of the city of Chicago as being contam-

inated and that ice men are prohibited from selling the ice from that river.

1459 Q. Then if the sewage of these different places that I have indicated, (Riverside, La Grange and Maywood,) (Riverside being ten miles away), does empty into the Des Plaines river, and did empty at the time that you made your examination, purification of that sewage had been completed at the point that you made the examination. Is that correct?

A. Yes, sir; if the facts are such; provided, however, that the volume of water was sufficient, and the DesPlaines river at times can discharge as much as 600,000 cubic feet of water per minute.

Q. And assuming also that the sewage from these points above there was emptied into that river, before that sewage got to the point that you took your samples, it had been purified, and the water had been rendered potable, according to your anaylses, is that correct?

A. Yes, my analyses established the fact that during those two months the water taken from the DesPlaines river was potable before it reached the Drainage canal.

1460 Q. The principles of purification will apply to the Des Plaines river the same as to any other river, would they not?

A. Well, if the conditions were alike, of course.

1463 There is no general theoretical principal that sewage contaminated water from cities above, receiving an additional discharge of sewage from cities below, that the water of the river so contaminated at the time of the additional discharge will retard the purification of the stream. It all depends upon the practical results.

1464 Q. Is there any principle established by chemical science that holds the river would not purify itself of sewage that it has received?

1465 A. I don't know of any as applied to those conditions prevailing in the Mississippi river above the mouth of the Illinois.

At certain times during the year the water of the Mississippi river above the mouth of the Illinois, from three to five miles above the mouth of the Illinois, that water is potable; at other times it is not potable. It varies according to the amount of impurities. During the warmer period of the year the water from that river is always better than it is during the winter months.

1466 June, July, August and very often we have summer weather prevailing through the month of September.

1467 The potability increases in the spring slightly with the warm weather.

Q. Does the rain-fall in July affect the potability of the water in the Mississippi river above Grafton?

A. Assuming the weather is warm, certainly warm temperature will assist materially in purifying—it assists in making it potable.

1468 Q. Doctor, if the waters at Grafton were chemically decided to be potable, is not the conclusion irresistible that the sewage, however magnified or increased in the upper Mississippi has been purified by the time it got to Grafton?

A. It would demonstrate that the pollution of the Mississippi river above Grafton is of such a character that it does not affect the potability of the water of the Mississippi at the mouth of the Illinois.

Q. And how is that question of potability arrived at aside from the theory that running water purifies itself in a certain distance if the analysis of the water demonstrate beyond question that the waters at Grafton are potable? (Taking into consideration the fact that St. Paul, Minneapolis, etc., discharge their sewage into the Mississippi.)

1469 It is possible that such purification may take place, but it is necessary for various conditions all to co-operate to being favorable to such a result being obtained.

1473 Q. Now, if the water of the Mississippi river at Grafton is potable, doesn't it convey to your mind, as a chemist, that sewage discharged into that water at Minneapolis and St.

Paul and all the cities nursing the banks of the Mississippi river, has become purified to the degree of potability by the time it gets to Grafton, the point where you made your examination?

A. Stating as I have done, that I am not familiar with the conditions, whatever pollution there might have taken
1474 place in that Mississippi river above the mouth of the Illinois river, whatever pollution has taken place, it has been rendered sufficiently harmless by the time that water reaches the mouth of the Illinois as to render that water potable during certain times of the year, as I have stated. My opinion is that practically throughout the year the water of the Mississippi river above Grafton is permissible as good drinking water.

Assuming Grafton was a large city and I was placed in charge of the water supply of that city as a scientific man, I would consider that water from the Mississippi river potable and would advise the citizens of Grafton to use the waters of the Mississippi river above the entrance of the Illinois river for drinking purposes during those eight months without boiling and without filtering.

1477 The bacteriologists who hold that sewage polluted streams are not potable water, the views of those learned men, meet with the approval of my judgment.

1479 Q. Now if a condition of that character presented itself to you where a stream was chemically potable and bacteriologically contaminated, what would be your opinion as to the potability of the water?

A. If such a condition should exist—I don't know of any—if it should exist, that water would certainly from a general hygienic standpoint, not be considered potable because the bacteriological pollution would certainly stamp it as unpotable, as not potable.

1481 I adopt the rule that all sewage contaminated streams are not potable, but I do not accept it as a hard and fast rule for every possible care, disregarding entirely the various

conditions that should come into consideration. It is possible that the rule may be applicable to the Mississippi river above Grafton, providing that the conditions prevail that will justify its application. I do not know whether those conditions prevail or not. I don't make the Mississippi river an exception to that rule. I can not tell whether it comes within that rule unless I make an examination of the conditions necessary to form an opinion.

1483 I have examined both conditions chemically and bacteriologically and thereupon formed a conclusion that the water of the Mississippi is potable three and five miles above the mouth of the Illinois. I did not make a personal analytical examination at the points above indicated, neither did I make a bacteriological examination. I do not know from my personal knowledge whether the waters at that point were bacteriologically pure, or not.

1484 The information I have has been reported by bacteriologists who made examinations at that point.

Excluding the opinions of everybody and basing my opinion upon my personal knowledge I cannot say that the waters of the Mississippi river three miles above Grafton are potable bacteriologically and chemically, that is, based upon personal analytical investigation of my own, so that when I testify as to the potability of these waters, my answer is based upon my personal research as a chemist. If the bacteriological information that I base the final conclusion on, is erroneous, I would certainly modify my views accordingly.

1485 I have no opinion of any bacteriologist who holds that the waters of the Mississippi above Grafton are potable. I form my own opinion from the study of analytical data.

1490 If Dr. Ravold drew the conclusion that the waters of the Mississippi river were not potable at Grafton, I differ with him in his conclusions, that is, vieved from a general hygienic standpoint.

1492 I consider the waters of the Missouri river potable at Ft. Bellefontaine, the station in the Missouri river where

we collected samples of water. Bellefontaine is five miles above the mouth of the Missouri. The water is more or less potable all the year around. It varies according to the seasons.

1493 I would consider the water found at Ft. Bellefontaine station potable throughout the year to a varying degree. Sioux City empties its sewage into the Missouri river. So does Omaha. Omaha has large packing industries and large distilling interests. Across the river from Omaha is Council Bluffs, which is quite a manufacturing town.

1494 They discharge their sewage into the Missouri river. So does St. Joe, Leavenworth, Atchison and Kansas City. Kansas City has great industries in the packing and slaughtering business. It has distilleries, too.

MR. JEFFRIES: I object to all the questions and move that they and the answers be stricken out.

1495 The sewage of Jefferson City empties into the Missouri river. So does Herman, Missouri and St. Charles, Missouri. The reason the Missouri river at Bellefontaine is potable, when all these cities and towns that have been mentioned here empty their sewage into the Missouri river, depends very much upon the amount of sewage which these cities discharge into the Missouri river. It depends furthermore upon the volume of water in the Missouri river. It depends also upon the velocity of the flow, the general conditions of the course of the Missouri river, what accessions of soil in the form of clay and silt the Missouri river takes along its winding course and what effect sedimentation of this enormous quantity of soil will have on the sanitary character of the water. There are various conditions that obtain in the Missouri river that do not obtain in the Illinois river.

1496 The water in the Missouri river is generally larger. The courses that the Missouri river takes is one of a great many bends and curves, much more so than the Illinois river. There are, as I have said, enormous accessions of soil swept along the course of the river from the shores of the river into the Mis-

souri river. This is not the case in the Illinois river. Heavy sediment of clay will produce at such points along the river where the velocity is slow, particularly if there are many bends and curves, considerable sedimentation along the banks. The Missouri river overflows and this overflow will cover vast areas of land sometimes. This helps the purification because sedimentation, according to the accepted axiom of modern science, will assist materially in purification. These conditions prevail from my own observations along the Missouri river between Kansas City and St. Louis.

1497 Between Kansas City and St. Louis I might have seen ten square miles that were overflowed, but I could not say positively that it was that much. Since these conditions prevail along the route between Kansas City and St. Louis from information that I have I should think it would have a considerable effect in the purification of the Missouri river.

1498 Q. Is there anything else more beneficial for the purification of that stream than that?

A. It has a character of great stability which I would distinguish as a chemical characteristic. Stability in contradistinction from instability would be that the processes of purification have reached the stage where the final product of the nitrifying cycle, that is, the oxidation of the free ammonia to nitrites and nitrates has reached a stage so that it is largely completed as is always evidenced in the Missouri river between those points that I have mentioned, by low nitrites, and uniformly low nitrites between Kansas City and St. Louis and comparatively high nitrates. I do not know how far below Omaha and Council Bluffs the water becomes purified and potable after the sewage has been emptied into it. As regards the point of purification, the question could not be answered.

1499 Because the conditions are such in the river that while the water in the channel below Omaha might show chemical improvements after the sewage of Omaha has been discharged into the river, the water running along the shore line would not show that to that extent. Because it is a well known fact that the sewage from cities is discharged on the shore. It

flows along the shore where there is supposed to be a current of less velocity than the current in the channel. The sewage may appear in this shore water whereas the channel current is entirely different water. It does not get into the channel until at high stages of the river when flood water comes down. The serpentine course of the Missouri river would not necessarily serve to get the sewage in the channel. It would be impossible for me to say that the sewage would be purified 20 miles down from Omaha.

1500 If the sewage should be placed in the channel sometimes it would take longer to purify it than it would along the shore on the banks, because it would depend somewhat upon the character of the water, the velocity of the stream and the character of the water the velocity of the stream and the character of the sewage being flushed from the shore into the channel.

1501 It would take longer for the sewage in the channel to purify than it would if it remained in a quiescent stage in the overflowed banks along the shore. The conditions in the channel of the Missouri river are such that usually when the sewage of the cities is flushed into the channel that it has previously undergone a certain stage of preliminary purification along the shores in the sediment of the banks which are overflowed at those points in this poorly regulated river.

1502 I know that it is a fact—I have obtained it from analytical data from those points. I have never seen the sewage of Omaha and Council Bluffs when it entered the Missouri.

1503 At that point I could state it is a theory. At Kansas City I investigated the conditions there but I have not seen the sewers myself. It is a theory justifiable from analytical data obtained. As to Kansas City I have no personal knowledge based upon observation as to how the sewage enters the Missouri river, nor as to Leavenworth and St. Joseph. I have not seen the sewer outlets of any of these places with my own eyes. If you define it as personally known to me (as to how long the sewage remains along the banks instead of entering the channel) I say it is a theory.

1505 I have no opinion based upon scientific data as to how long it would take the sewage from Omaha, Council Bluffs, Kansas City, St. Joseph or Leavenworth to purify itself. I have no opinion in regard to any of the cities located upon the Missouri river as to how long before the sewage from such cities would purify itself, if emptied into the channel.

I have a reason why the water at the point of Bellefontaine is potable, based upon investigations I made of the Missouri river. Those are the great length of the river, its many
1506 curves and bends, its many sedimentation beds along its course and the long time water takes to flow all this distance from Kansas City. The distance from St. Louis to Omaha by the water line of the Missouri river is 676 miles; to Kansas City it is 403 miles; from Omaha to Kansas City is 273 miles. The character of the sewage entering the Missouri river at Kansas City is a sewage very high in percentage of refuse matter from slaughtering houses and rendering establishments and it contains 60 per cent of the sewage of Kansas City as discharged into the river. This sewage, of course, includes the fecal matter, it includes all the dirt in the streets as
1507 swept into the sewers from rainfall or from street sprinkling. There is considerable sewage entering the river from slaughter houses and other manufacturing establishments.

Q. Does that sewage from Kansas City purify itself in the Missouri in going 400 miles?

Objection by Mr. Jeffries.

A. Whenever sewage pollution has taken place from the sewage of Kansas City, that sewage pollution has to such an extent disappeared when the water reaches Fort Bellefontaine, after a run of 403 miles, that water is potable at Fort Bellefontaine.

1508 In a normal stage I am of the opinion that the Missouri river is slightly swifter than the Illinois. When the Missouri river is low and the Illinois river is low, the velocity of these two streams would be about alike. The average velocity of the Missouri river would be from three to three and one half miles.

1509 I have been at times on the Illinois river when the current was one mile and then again, when it was declared to be two miles, but not from my own investigations. At times, at high water, I have known that it was three miles an hour. The current can go up, at high water, in the Missouri, to four miles an hour.

1510 It is very likely that I have analyzed waters taken from the river at Bellefontaine when the current of the river was four miles an hour.

Q. How can you state that the waters of the Missouri river all the time are potable, in view of the fact that when the current of the river is four miles an hour and it is only 403 miles from Kansas City to St. Louis, which at that rate would be four days for the sewage to get from Kansas City to St. Louis, that the water is potable?

A. I can only form the conclusion that the water is potable, from the chemical analyses performed upon the water taken from the Missouri river at Fort Bellefontaine and the water was potable.

1511 Q. If your analytical data is correct, would not it justify the conclusion that when the current of the river is four miles an hour that it will purify itself in running a distance of 403 miles?

A. I can not draw the conclusion that sewage will purify itself in four days' running, because it can not be ascertained whether it came down in four days.

1518 In my examination at Fort Bellefontaine I found albuminoid ammonia in the waters of the Missouri river.

1519 The albuminoid ammonia in comparison with the free ammonia was considerably high. That indicates contamination of organic matter. If albuminoid ammonia is found in suspension more than in solution it will indicate organic matter due to contamination of vegetable origin.

Q. Why not animal origin, Doctor?

A. Because the organic contamination of animal origin is more represented in the albuminoid ammonia in solution. Because the organic matter of animal origin that is found in

solution in the albuminoid ammonia will represent to a large extent the pollution of animal origin in soluble forms. If the albuminoid ammonia is in solution instead of suspension to a high degree that will enable the conclusion that the origin of the organic matter may be more from animal sources.

Q. In what condition would you find the albuminoid ammonia from the sewage of slaughter houses—in suspension or solution?

A. Well, in both, very likely. In suspension would prevail the more largely. I found considerable high albuminoid ammonia in the Missouri river at Bellefontaine. It was partly in suspension and partly in solution.

1520 At times the albuminoid ammonia in suspension would be larger than the albuminoid ammonia in solution and at other times the reverse would show.

Q. If that is true, how would you distinguish between the albuminoid ammonia of vegetable and animal origin?

A. The distinction could be made from that point of view that the organic matter in suspension is very largely composed of such matter as is of vegetable origin.

The albuminoid ammonia found at Bellefontaine, Missouri, for a larger part of the time appears to be in suspension and the smaller part in solution.

1521 Organic matter is the origin or albuminoid ammonia, that organic matter may be from animal and it may be from vegetable origin.

Q. Is albuminoid ammonia derived from vegetable, the same ammonia that is derived from animal?

A. Well, as a product of distillation it is the same. There are no identifying characteristics of albuminoid ammonia when it is found, that will enable the chemist to say whether that ammonia came from vegetable or animal origin, if he bases his opinion solely upon the product of distillation.

1522 There is nothing in the albuminoid ammonia itself that will enable the chemist to ascertain whether it came from animal or vegetable origin, that is, not in the analytical product itself. In the Missouri river I found albuminoid ammonia in solution and in suspension in different degrees.

Q. When albuminoid ammonia is found in suspension does that indicate whether it is of animal or vegetable origin?

A. Well, that could not be determined from the analytical product itself.

Q. If albuminoid ammonia was in solution would that indicate whether it was from vegetable or animal origin?

A. Not if determined as found from the analytical product itself.

1523 When this albumen which we denominate albuminoid ammonia becomes disintegrated by bacteria or oxidation it gives what is known as carbonate or chlorid of ammonia. Then when the free ammonia by similar processes of oxidation or bacteria is broken up, it results in what is known as nitrites and the nitrites by similar process change into nitrates, the final product in the cycle of nitrification.

Q. So that in the beginning is what is known as albuminoid ammonia or albumen in the process of fermentation or purification?

A. Yes, probably carbonate of ammonia and chloride of ammonia, but including of course these almubinous compounds.

1524 Albuminoid ammonia is present in the sewage from slaughter houses and fecal discharges from man and animal. It is also found in the decomposition of vegetable matter.

Q. Doctor, as a chemist, do you enunciate as a principle of chemistry which you yourself by your analytical investigations have established, that albuminoid ammonias in suspension indicate vegetable origin, and albuminoid ammonias in solution indicate animal origin?

A. I said that they may be present in both; not altogether in one.

I can differentiate between albuminoid ammonia of vegetable origin and that which is of animal origin by taking into consideration the oxygen consumed results, which enable, in a measure, an opinion as to the vegetable or animal origin.

1528 Q. Can you tell from the presence of nitrites whether the nitrites come from vegetable or animal origin?

A. I could only take the general results of the entire analyses and certain local conditions as they are prevailing at the point where the sample is taken.

Q. That is, if you knew, independent of chemistry, that the water was sewage contaminated from the sewage of man or animal, then the nitrites appearing there, you would draw the conclusion that they came from animal rather than vegetable origin? Is that correct? A. Yes, sir.

Q. If you did not know the origin but only had the nitrites to go upon, could you tell whether it was of vegetable or animal origin?

A. No, sir, not if I took the nitrite results by themselves, I could not do it.

1529 I can not tell by the presence of free ammonia in itself whether it is of animal or vegetable origin, nor of nitrites,, nor of nitrates. Nitrates come from nitrites and nitrites from free ammonia; free ammonia comes from albuminoid ammonia.

1530 High chlorines in a river may indicate sewage pollution and they may indicate the passing of the river through a deposit of salt in the geological structure. It is uncertain what it indicates for chlorines alone.

1531 The sewage from all the cities upon the Missouri river entering into the Missouri river carries with it sodium chloride and in addition to that, I have testified about the Kaw river. As a chemist I can not distinguish the sodium chloride which comes from sewage and that which comes from the beds of the Kaw river, as I have testified.

In a measure, I took into consideration, in drawing my conclusions as to the conditions of the Missouri river as to its potability, the sodium chloride which entered that river from the sewage of all the cities along it. There is a certain amount of chlorine found in the Missouri river above the mouth of the Kaw river. The analyses show that and also a certain amount of chlorine is found in the Missouri river after the Kaw river empties into the Missouri river. When it got to Bellefontaine, I was not able to state what percentage of the chlorine I there

found came from the sewage, and what percentage came from the Kaw river, whether the percentage from the sewage was larger than the percentage that came from the Kaw river, I am not able to ascertain chemically.

1532 The conclusion is justified that since the average chlorines are uniformly higher between Kansas City and Bellefontaine, that since as much as 100 parts per million, or five and six times as much chlorine is found in the Kaw river, that the Kaw river certainly is responsible for the high chlorine prevailing between Kansas City and Bellefontaine, as compared with the chlorines between Omaha and Kansas City. The Kaw river enters the Missouri above Kansas City.

1533 The Kaw river chlorines show 100 parts per million. The Missouri river after the Kaw river discharges into it may not show more than 24 parts per million of chlorine and above the Kaw, it might be 16, that would show an increase in the chlorines of the Missouri river resulting evidently from the mixture of the two rivers. The samples I took in the Missouri river were taken below Kansas City, that point had received the sewage of Kansas City, in addition to the volume of water from the Kaw river.

1535 The sample that was taken above Kansas City was taken above the mouth of the Kaw river.

1536 Took three samples all together below Kansas City, Missouri. The sample that I took above the Kaw river in the Missouri river showed on the day of collection, 16 parts per million of chlorine. The sample taken in the Kaw river showed on one day 100 parts per million of chlorine.

1537 The Missouri river sample below Kansas City showed 24 parts per million of chlorine. Above Kansas City showed 16 parts per million, which shows an increase of one-third in the chlorine. Since that day the Kaw river showed very high chlorine—80 to 100 parts per million—the conclusion could be drawn that so much chlorine coming from the Kaw river into the Missouri river would affect the quantity of chlorine found in the Missouri river below Kansas Ctiy.

1538 Q. Doctor, in the absence of the known volume of the Missouri and of the Kaw, do you take into consideration

the sewage contamination from Kansas City, Missouri and Kansas City, Kansas, as to the chlorines?

A. Well, I didn't in this case. I admit that a definite conclusion could have been drawn if the quantity of chlorine coming from the sewage into the river could have been ascertained, but that is an impossibility and, on the other hand, the Kaw river showing such tremendously high chlorines, I considered it a natural conclusion that there must be some effect of the high chlorines in the Kaw on the increase in the Missouri river.

1539 I eliminated from my opinion or conclusion, the volume of water in the Kaw, the volume of water in the Missouri and the sewage of Kansas City.

1540 The volume of water in the Missouri above Kansas City varies considerably. It may be 100,000 cubic feet and it may be 600,000 cubic feet per minute. I have no accurate data as to the Kaw, nor as to the volume of sewage that enters the Missouri river from Kansas City, Missouri and Kansas City, Kansas, except that I have ascertained from the city engineer of Kansas City, Missouri, that only 60 per cent of the population drain sewage into the river directly. In order to draw a conclusion as to whether the chlorine below Kansas City comes from the sewage of Kansas City, Missouri and Kansas City, Kansas, or from the Kaw river, it is important to know the volume of the Kaw and the amount discharged into the Missouri from those cities. Such knowledge would enable an absolutely accurate estimation.

1541 Q. Your conclusion then is not accurate, is it?

A. Well, I consider it an approximation. If the Kaw river was only a river of two or three hundred cubic feet per second, emptying into the Missouri with the volume I have indicated, that would dilute the chlorines in the Kaw flowing into the Missouri enormously. Those very analyses I presented show that they are reduced from 100 in the Kaw to 24 parts per million in the Missouri, which is an enormous dilution. I cannot say what proportion of the increase of chlorine below Kansas City is due to the Kaw river and what to the Kansas

City sewage. I don't know whether 90 per cent of it is due to the sewage or not.

1543 Q. Doctor, why didn't you take into consideration the sewage from Kansas City in your conclusions in regard to chlorine?

A. I had no available data. I could not obtain them. It would have necessitated an investigation which I could not undertake at that time.

1544 In none of my investigations have I taken into consideration the sewage discharge of Kansas City, in calculating the chlorines for the Missouri river. It was because I could not obtain the data that eliminated the sewage of Kansas City entirely from my consideration. I relied upon the condition of the Kaw river as found, to justify the approximate conclusion.

1545 Q. Then you don't know what proportions of the chlorines below Kansas City came from Kansas City and what came from the Kaw river, do you?

A. Not from any investigation of the Kansas City sewage.

1546 Q. Now the chlorines that you found at Bellefontaine, you are unable to say what proportion of those comes from Kansas City sewage and what porportion comes from the Kaw river?

A. I feel justified, when the Missouri river is low and I find high chlorines at Ft. Bellefontaine that those chlorines can come from the Kaw river chlorines largely, if not altogether.

Q. Assuming that 90 per cent of the chlorines found at Bellefontaine comes from the Kansas City sewage, would that have any effect upon the potability of the waters of the Missouri river?

A. Not unless corresponding high nitrites and correspondingly high free ammonias would be shown.

Q. If correspondingly high nitrites and correspondingly high free ammonias were shown and the albuminoid ammonias you were not able to ascertain whether they were from animal or vegetable origin, could you tell?

A. And how much chlorine would be in that calculation?

Q. The amount which you found by your analyses. Would you denominate that water potable?

A. If the nitrites, chlorines and ammonias were high and I was personally convinced that the chlorines were due to sewage and not from the Kaw river, I would say, according to the axiom of sanitary science, that the water was not potable.

1548 Q. If the albuminoid ammonia should be of animal origin and accompanied by high nitrites and nitrates and free ammonia and high chlorines, the water would not be potable, would it?

A. It would not, if accompanied by those other high ingredients you mention.

1549 You could have high ammonia in solution and in sus- never found high nitrites in the Missouri river. The nitrates are high.

1552 Q. Now, if you have got high albuminoid ammonia, free ammonia, low nitrites, high chlorines and you do not know what the source of that chlorine is, would you say the water was potable, or not?

A. I would base my judgment upon the conditions prevailing and the source of that high chlorine.

1553 I would refuse to give an opinion without that information. The waters of the Missouri river at Fort Bellefontaine are what is known as stable waters. The term "stable" is applied to a river where the fermentative changes and the nitrification changes which the impurities in the river undergo are more of a uniform character and are going on in the manner that they do not change rapidly and where analy-

1554 tical results show by uniformly low nitrites that the cycle of purification has reached a stage where a large portion of the impurities have been converted into nitrates, the final product of the cycle of nitrification.

1554 I found the albuminoid ammonia in the waters of the Missouri at Bellefontaine quite high. I found the free ammonia as a rule, which I consider low, but at times I found a slight increase in the free ammonia, where I would say that

the free ammonia was there in a considerably quantity. The nitrites I found uniformly very low for a river. The nitrates I found at times quite high. The chlorines I found high, sometimes as high as 46 parts per million. The Missouri river was a polluted stream at Fort Bellefontaine based upon my chemical analyses.

1555 Its pollution is variable, you could not define it. That is, you could call it a polluted stream. I would not call it a very polluted stream. I attribute the pollution to organic matter of vegetable and animal origin, the degree of each varying. I am approximately able to state from my analyses the extent of pollution attributable to vegetable origin and to animal origin. Applying the same principle in determining the vegetable origin of the organic matter, I would say that whenever the albuminoid ammonia in solution runs very high with the organic matter—as estimated by the oxygen consumed process—high and the nitrites, although uniformly low, would still show their presence by a figure showing that there was still fermentative changes going on at that time—at such times I would say that the pollution could be of animal origin. At such times the water was not potable.

1556 The conditions I have just described would obtain during the winter months. Absolutely considered as winter months, I would consider from three to four months. During those four months this condition of pollution that I have described as being attributable to animal origin obtains in the Missouri river.

1557 During that time the waters of the Missouri are not potable.

Q. Then when you stated in your testimony yesterday that the Missouri river was potable throughout the year, you eliminated from your consideration the four winter months, during which animal contamination existed in the Missouri river?

A. I am very glad that you brought that matter up, because if I said "throughout" I did not mean to say that. What I meant to say was, "prevailed during the year," in taking the

larger part of the year when I think the water is potable but for those four months I do not consider it potable. As to the other eight or nine months of the year when I claim the water is potable, that condition was ascertained by chemical analyses. I have supplemented my chemical analyses by bacterial investigation. The waters of the Missouri river are not bacterially pure. The bacilli coli communis I consider are found in smaller quantities in the Missouri river during those summer months than in the winter months.

1558 The presence of bacilli coli communis may indicate either sewage pollution, if corroborated by chemical analyses or may indicate fecal discharges of fish. There are many fish in the Missouri river. Since investigations have determined that fish have in their fecal discharges the colon bacillus, and if the chemical analysis does not demonstrate sewage pollution of the waters, the conclusion may be reached that sewage not being identified as present by the chemical analyses, the presence of the bacilli coli communis may be ascribed to the fecal discharges of fish. It is some time ago since I have studied data and reports on such investigations and at this moment I cannot remember whether it has been proven that bacilli is present in fish in streams other than sewage contaminated.

1560 Outside of the data secured from Dr. Ravold I have not made any independent investigations on the line of bacteria in the Missouri river. From the data compiled by Dr. Ravold, I consider the Missouri river potable during these eight or nine months that I have specified as representing the warm season of the year—potable at Fort Bellefontaine.

1562 The Missouri river at various points is sewage polluted wherever the sewage enters the river from cities along the line.

Q. Do you know of any scientific man who has investigated the waters of the Missouri, who holds to the doctrine that it is potable, aside from yourself?

A. Well, if I understand the testimony of Prof. Keiser correctly, he testified to that effect. From a bacteriological standpoint alone, a running river should not be judged as to its potability. The chemical condition should be taken into consideration. I do not know of any other authority on bacteriology who holds that the Missouri river is potable.

1564 Q. Assuming that the conditions existed at Bellefontaine as you found them, by your analyses, and that the high chlorines that you found there were attributable to the sewage discharge of Kansas City, what would be your conclusions as to the stability of the Missouri river at Fort Bellefontaine?

A. Even if those high chlorines you mention there were due to the sewage from Kansas City, after a run of 403 miles, even then it would be very difficult to ascribe such character to the water as you hypothetically present to me as due to sewage pollution from Kansas City, for various reasons—first of all, the distance from Kansas City to St. Louis would be 403 miles by water. Only 60 per cent of the Kansas City sewage would go into the Missouri river. The Missouri river during its winding course, with many curves, there being no dams or anything, the river overflowing frequently during its course, carrying a great deal of sewage over vast places adjoining the river, and at a low stage of the river, as the river falls, much of this sewage never coming down the river, being left there in a condition of fermentation, on that soil, previously overflowed. It would be impossible to claim that any Kansas City sewage reached St. Louis or reached Bellefontaine.

Q. Then the conclusion is irresistible that the sewage of Kansas City has become purified before it reaches Bellefontaine, in going a distance of 403 miles?

A. At certain times, when all of such conditions would prevail as I describe, I would say yes.

1565 The distance that the stream would purify itself from Kansas City would depend upon the velocity of the current and the condition of the river itself, that is, in enabling

the overflow over large banks. It is a uniform rule that the waters in the Missouri, with the higher stage of water, have a swifter current in the channel.

1566 The lower stage of water, the slower the current.

1567 I cannot tell how far above Bellefontaine the water purifies itself of the sewage of Kansas City.

1568 I know from the official statement of the city engineer of Kansas City that 60 per cent of the sewage of the population of Kansas City, Missouri drains directly into the Missouri river. I have no information about whether the sewage from the cattle and stock yards is included in the 60 per cent population.

1570 The time it takes nitrites, by the process of oxidation to become nitrates would depend upon the number of aerobic bacteria in the water.

1571 If the waters contain large quantities of bacteria the time would be lessened. In laboratory experiments we find that the nitrites found present in the respective samples of water on the first day disappear after a number of days and the nitrates increase showing that nitrites have been converted into nitrates.

Q. Supposing that there would be a great number of aerobic bacteria present in the water and the nitrites were not in a large quantity, how long would it take?

A. This process would be a very rapid one. It might take 24 hours and it might take 48 hours for a small amount of nitrites to disappear. If the aerobic bacteria were present in the running water in great numbers that would have a tendency to decrease the nitrites even in the water.

1574 The presence of clay and silt in water is evidence of a greater number of these bacteria that possess the nitrifying effect upon the nitrites. The conclusion is justifiable that they are there in great numbers. There are more nitrifying or so-called oxidizing aerobic bacteria in the Missouri river

water than in the water of the Mississippi and that, of course, would accelerate the oxidizing action in that water.

1575 The laboratory experiments show in the analytical results of water of one sample collected day after day from the same original sample that the changing of the ammonia into nitrites is slow, that is, the reduction per day of ammonia in quantity as estimated by analyses was very small, whereas the reduction of nitrites was large and small amounts of nitrites would, as I said, disappear in a period of from 24 to 48 hours. The samples taken at Fort Bellefontaine arrived at the laboratory three or four hours after they were taken. The nitrites were determined immediately upon arrival of samples.

1577 Q. Can you state, Doctor, as a positive fact that the low nitrites which you found in the waters of the Missouri at Ft. Bellefontaine are not attributable directly to the action of these bacteria from the time of the taking of the sample up to the time of the analysis?

A. If such a reduction of nitrites to nitrates, or rather oxidation—to be absolutely scientific—if oxidation of nitrites to nitrates took place in those samples while they were in transit from the station at Fort Bellefontaine to the laboratory, it would be so inappreciable that it could be disregarded because of the fact that the samples were packed in ice and kept at a very low temperature from the time they were collected until the time the chemist would take the sample, open the bottle and make his nitrite test.

Q. How do you know that, Doctor, as a scientific fact, is applicable to the waters of the Missouri?

A. From comparative tests that I made on a boat analyzing samples for nitrites probably ten minutes after they were taken from the place of collection and analyzed on the boat, and comparing the result with samples packed in ice and taken to St. Louis and analyzed. From these tests I have come to the

conclusion that the oxidation of nitrites is inappreciable for six hours at times and other times, at eight hours, if the samples were properly packed in ice.

1578 These were Mississippi river samples; they were not Missouri river samples. There were no bacteriological approximations made on the number of aerobic bacteria from these samples.

1580 I made no investigation in any of my analyses for the presence of aerobic bacteria in the waters of the Mississippi. The oxidation of nitrites depends upon the presence of these bacteria. If this bacterium is present in large quantities oxidation will be facilitated provided there is also a large quantity of dissolved oxygen present in the water. There may at times be more dissolved oxygen found in one river than there is in the other.

1582 I have never made an examination of the waters of the Missouri river at Fort Bellefontaine at the time they were taken out of the river.

1584 In making my analyses I looked for causes so far as the water is concerned, on the route between Chicago and St. Louis. As regards Fort Bellefontaine samples, I only looked for the condition of the water at Bellefontaine and did not look for the causes.

1585 I don't admit sewage pollution at Fort Bellefontaine from Kansas City or the stock yards.

1586 I looked for causes partly during that period when the investigation showed pollution at Fort Bellefontaine. I considered it my duty to ascertain what this pollution might be ascribed to.

Q. Then your answer to my previous question that you were looking for effect and did not take into consideration the causes, you wish to modify, do you?

A. That is to be applied to that period when I found that water good and potable, then it was unnecessary to look for any cause but during that period of the investigation when I would

find the Missouri river water polluted, I made an effort to ascertain the causes of that pollution.

1587 When I found the water pure or good at Fort Bellefontaine I did not look for the causes which created that good condition of the waters. I was mindful all the time in my investigations that the sewage of Kansas City, Missouri and Kansas City, Kansas, and the other towns located upon the Missouri river was emptying into the Missouri river. As long as I found the water good, I did not look for the causes that purified the water from the sewage contaminations of the cities above.

Q. Are you able to state what made the waters good, with the knowledge that there was sewage pollution at Kansas City and at other points?

pension in the Missouri river from vegetable origin. I

A. Nobody could state that. That is impossible.

Q. Then that is a matter outside of the realm of scientific research?

A. No, sir. I can not name anybody who could tell. Scientific men give an explanation from stating the general conditions in the Missouri river between Kansas City and Bellefontaine.

1588 It is problematical.

Q. But it is not problematical what becomes of the sewage of Chicago, is it doctor?

A. The Chicago sewage is entirely different.

Q. Has the light of scientific truth shone more clearly upon the chemical and bacteriological mind in regard to the Chicago sewage than that of the Kansas City sewage?

A. The conditions of the two rivers are so materially different, the quantity of sewage coming from Kansas City being discharged into the river is so materially different from the sewage being discharged from Chicago into the Des Plaines river, the conditions of the Des Plaines river and the Illinois river vary so much from the conditions prevailing in the Missouri river. The distance between Chicago and St. Louis for

the sewage to run is 357 miles and the distance from Kansas City to St. Louis is 403 miles, making 46 miles difference.

1591 I have estimated in volume the sewage discharged from Kansas City, Missouri and Kansas City, Kansas, by usual or customary calculation.

Q. After you find that out, what use did you make of it?

A. Well, I studied the conditions of the Missouri river and I utilized the data in the customary way such conditions are studied.

1592 Q. Why didn't you take into consideration in ascertaining the source that chlorine came from the sewage of Kansas City, Kansas, and Kansas City, Missouri, when you made the test below Kansas City?

A. Because it is difficult to estimate from the volume of sewage discharged into that river the quantity of chlorine.

Q. How much of the chlorine that you discovered in your analyses below Kansas City was attributable to the sewage of Kansas City, Kansas, and Kansas City, Missouri?

A. That is a question which I yesterday answered that I could not tell, because I had not made investigations as to the quantity of chlorine to be found in the sewage discharged from various outfalls into the Missouri river because of the extreme difficulty in ascertaining the amount of chlorine there. The amount attributable to the Kaw river would vary much. It depends upon the volume of water in the Missouri.

1593 Q. Is there anything in connection with the chlorine itself that will enable you to tell whether it is mineral pollution, as evidenced by the discharge of the Kaw, or sewage pollution as evidenced by the sewage of Kansas City, Kansas, and Kansas City, Missouri?

A. Yes, sir. As I explained yesterday, the fact that the analytical results of the water at Fort Bellefontaine do not show correspondingly high free ammonia and chlorines and nitrites together, and that the nitrites are uniformly low

1594 is no justification to ascribe the high chlorines to sewage pollution.

Q. The question is, is there anything in the chlorine itself?

A. No, sir.

Q. Then the only reason that you attribute the presence of chlorine at Fort Bellefontaine to the Kaw river and not to sewage is based upon consideration aside from the chlorine itself?

A. No, sir, in determining that question it is necessary to take into consideration the general analytical results as found from the analyses of the samples at Fort Bellefontaine. If the chlorine is due to sewage pollution there should be high nitrites, high free ammonias and high organic matter would show in the results. If the nitrites are low and the free ammonias low as it usually is in the Missouri river this high chlorine cannot be attributed to sewage pollution. It must come from mineral matter, it must come from salt. The determination of the sources of chlorine must be had from outside considerations, aside from the chlorine itself and that determination is based largely on low nitrites, high free ammonias and high
1595 chlorines. I believe I stated that albuminoid ammonia would come into consideration as organic matter either high or low. If the free ammonia were low that is the most essential point involved there. The free ammonia for the major part of the year is very low in the Missouri river. The nitrites are either very low or absent entirely.

Q. Assuming that the general analytical results show albuminoid ammonia, free ammonia, low nitrites, chlorines in the amount that you found it, but that the chlorines were attributable to sewage pollution and that there was no river Kaw?

1596 A. Well, if it would be an established fact that the chlorine was due to sewage pollution, why that water in itself would be unpotable because of its sewage origin. If the chlorines were identified as coming from sewage pollution, the presence of the other ingredients going with it would of themselves form a part of that conclusion, because the fact is then established as such that the chlorine is due to sewage pollu-

tion. In making the nitrite test, alum was added to the
1597 water to clarify it. After the addition of alum, the water was filtered. I have known that the waters were
1598 potable since 1899. I have always been an advocate of using Missouri river water for consumption in the city. I have agitated the use of the Missouri river water in preference to that of the Mississippi at the present intake. I first entertained those views in regard to the Missouri water being the best water to be used in the city of St. Louis in 1899. I first became connected with the city as chemist in 1893. At that time I knew of the contemplated building of the Drainage canal.

1599 Q. From 1889 on to 1893 or 1894, was anything said about the canal and its construction in the papers of St. Louis that you know of?

A. Yes, sir. The matter was discussed in the year 1893 to some extent. It was a matter of general knowledge in St. Louis that this improvement was being made in Chicago. It came up before the Board of Health in the form of a discussion of a resolution introduced in the year 1893. I believe the Health Commissioner of St. Louis at that time—Dr. George Homan—introduced the resolution. One resolution in 1893 was that in view of the construction of the Drainage canal at that time going on in Chicago, a National Board of Experts should investigate the question as far as it would affect the water supply of St. Louis and questions in general pertaining to sewage pollution. The Board of Health recommended in the resolution either that Representative Barthold of St. Louis, in Congress, should introduce a measure asking for such an investigation, or that such a measure had already been introduced by Mr. Barthold and was supported by this resolution. The other resolution was calling upon the city chemist to perform some analyses of water. He was to collect them from the mouth of the Illinois down to the city of St. Louis at that time, from the Mississippi river and the Illinois river.

1600 I don't recollect whether the recommendations of the Board of Health made to the Mayor of St. Louis for an injunction suit in the Federal Courts against the construction of the Drainage canal whether that was the result of the analyses that I made of the water or whether it preceded this investigation. I cannot recollect at this time because it is nearly ten years ago.

Objection by Mr. Jeffries.

I made a cross-section of the waters in the Mississippi river above Grafton. I did not make a cross-section of the waters of the Illinois river before the same entered into the Mississippi river at Grafton. I made a cross-section of the Mississippi river below Grafton, at Alton and at Hartford.

1601 Five samples were taken at Alton in that cross-section. That is, whenever a cross-section was taken, five points were selected in a line across the river and the samples taken at that point. The number of days when these cross-sections were taken cover about a month—every day. The samples taken at Alton were practically taken during the same months and days that the samples were taken at Hartford. There were a few samples taken at one point I believe which the record will show. They cover the same period of time in both places. It was the month of November, 1901. I also made a cross-section at the Chain of Rocks, St. Louis waterworks. 12 samples were taken across the river on five different days from November 25 to November 30. There were some cross-sections taken from the Illinois river at points betwen Peoria and Pekin and at Pekin. No samples were taken at the mouth of the Illinois river for cross-sections.

1603 At Fort Bellefontaine on the Missouri two cross-sections were taken. Eight samples were taken across the river November 29, then again on the following day on November 30, another cross-section was taken at Fort Bellefontaine. There was no other place in the Missouri river that samples were taken in cross-sections. Alton is 16 miles below Grafton. Hart-

ford is 14 miles below Alton, and nine miles above the
1604 Chain of Rocks. The distance between Pekin and Grafton is about 140 miles. Cross-sections were taken at Pekin bridge on November 12, 16, 19, 23 and 26, 1901, two samples on each day.

1605 Q. Now in order to ascertain between the 25th and 30th of November, at the Chain of Rocks, the component constituents of the waters of the Mississippi as to whether the water there was Missouri, Mississippi or Illinois water, you would be confined to the data from the period between November 29th and 30th, would you not, as those are the only two days that the cross-sections were made in the Missouri river?

A. Well, if the conclusions to be derived from the analytical data would depend upon the cross-section—

Q. Well, doesn't the conclusion which you arrive at depend upon the cross-sections?

A. That depends upon conclusions in what respect, because I—

Q. As to the character of the waters at the Chain of Rocks in the Mississippi river?

A. Not altogether.

Q. Then what was the purpose of taking 12 samples of water across the Mississippi river at the Chain of Rocks, between the period of November 25th and November 30th daily?

A. I said that it was not dependent altogether upon those cross-sections, but the cross-sections of course gave me certain information that I wanted to obtain from the cross-sections in order to obtain facts that the cross-sections would reveal to me.

Q. Well, when the cross-sections failed to reveal the facts that you were looking for, would you go anywhere else for those facts? A. Yes, sir.

Q. Where would you go?

A. Well, I would take all the analytical data that I could obtain on that qusetion and consider them from a general standpoint as every chemist would.

1606 And what were you trying to prove by cross-sections,—these waters mixed and went into the intake?

A. Yes, sir.

Q. And if these cross-sections did not reveal that fact, then you went elsewhere to find that fact to prove that they mixed and went into the intake, did you?

A. Well, I said in connection with the general analytical result, I would take the result of the cross-sections and consider them.

Q. But you would not consider them by themselves, would you?

A. Not in determining that question entirely. I would take into consideration the total solids, which total solids were not estimated in these cross-sections that I looked for.

Q. If this cross-section made at the Chain of Rocks, at Hartford, Alton, Bellefontaine and at Pekin did not prove conclusively to your mind that the waters of the Illinois river entered the intake of the city of St. Louis, did you go any where else for any facts in order to establish that fact?

A. Well, in reviewing the analytical results from these cross-sections my views were strengthened as to the currents coming down the Mississippi at the Chain of Rocks.

Q. Then before you made these cross-sections you had views that the waters of the Illinois entered the intake tower of the city of St. Louis, did you not?

1607 Yes, sir. These cross-sections were made to confirm that view as far as nitrites and chlorines could confirm that view, because I only took cross-sections for that purpose. These conclusions that I drew were to my mind sufficiently definite to dispense with a further investigation of that problem. Those cross-sections did not establish independently the fact that the Illinois river went into the St. Louis intake. I had formed an opinion on that question prior to the taking of the cross-sections.

1608 In the Missouri river I only took two cross-sections on November 29th and 30th.

Q. Wouldn't it be fair to limit your investigations in the cross-sections at the Chain of Rocks in ascertaining the St. Louis water, to November 29th and 30th?

A. No, sir, that wasn't necessary because I had practically formed on opinion as to that question prior to the taking of those cross-sections.

1613 On the 29th of November the Missouri river itself would press the waters of the Mississippi toward the Illinois shore by the time it got to the Chain of Rocks. It will always push the water somewhat toward the Illinois shore because of the manner in which it comes down the Missouri river and during a larger part of the year this volume being quite large, it would press the Mississippi river somewhat toward the Illinois shore, it follows that if the pressure is very great and the volume of the Missouri river very large and the volume of the Mississippi river not so large, that the pressure of the volume of water would push the Mississippi so close to the Illinois shore that on such days nothing but Missouri river water would enter the intake at the edge of the channel in the Mississippi.

1614 At other times, the condition might be the reverse and then the intake being located 1,500 feet from the Missouri shore, would receive at that time nothing but Mississippi river as it comes down the river. There has been a sand-bar formed in the Mississippi river just above the intake. It can happen that the water would sweep around that sand-bar and I have seen considerable of an angle, and be pushed over toward the Missouri shore.

Q. And keep the Missouri river towards the Missouri shore?

A. Yes, push it a little more toward the Missouri shore because this water at an angle, it would come around that sand-bar with considerable pressure and would press the Missouri closer toward the Missouri shore. At such times, the water in the intake would be from the Mississippi.

1615 The analytical results of samples taken at Hartford and Alton in the Mississippi river as compared with the results of samples taken at the Illinois shore opposite the intake always show by comparison somewhat less in impurities in the sample of the Illinois shore at the Chain of Rocks. That would show some mixing effect of the Mississippi and Illinois rivers at the point on the Illinois shore if the sample was taken opposite the intake.

Q. Have you made any calculations of the percentages of decrease in nitrites of the waters of the Illinois from Grafton down to Alton, in going that distance?

A. No, but there is invariably a decrease noticeable in the analytical results of the nitrites found at Alton as compared with the samples taken from the Illinois river at Grafton.

1616 Q. Do you attribute that to the mixing of the Mississippi or to the natural fermentative changes that take place in the water?

A. I think that it may be due to either cause. It is difficult to determine to which cause in all those instances it would be due. It may be due to either and the same is true for the sample found at the Illinois shore at the Chain of Rocks. I have not made an analysis of the waters of the Illinois river for a distance of 39 miles immediately above its mouth to Grafton. I do not know how much the varying changes would be for the samples taken 39 miles above Grafton on the Illinois river.

Q. Do you know whether it would be any greater than is evidenced by your analysis from Grafton to the Chain of Rocks along the Illinois shore?

A. I don't think the change would be so great in the Illinois river from the point 39 miles as you state.

1617 On what do you base that, doctor? Have you made any experiments of it?

A. Because of the fact that the Mississippi river connects with the Illinois river at Grafton and that the Missouri river connects with the Mississippi river at the mouth of the Mis-

souri. That would change the conditions materially and bring about a different situation than exists in the Illinois river between the point 39 miles above Grafton and Grafton. I do not know what percentage of Mississippi water and Illinois river water is in the channel of the Mississippi river at Alton. There would be a way of ascertaining it. By comparing the general analytical data I formed the opinion that there is some mixture taking place in the channel.

1618 I thought approximations would suffice for the purposes of my investigation. The same condition obtained at Hartford. I made no investigation to ascertain the amount of Illinois and Mississippi river water at Hartford. When I got to the Chain of Rocks I could, by approximations, form a conclusion as to the relative mixtures there prevailing at the Chain of Rocks.

Q. Could you take a gallon of that water in the channel of the Mississippi river at the Chain of Rocks and tell how much of that water was Missouri river water, how much Illinois river water and how much Mississippi river water?

A. No, sir, not that way.

Q. Could you anyway?

1619 A. I could by careful study of the analytical data obtained from anaylses of samples taken in the Illinois river a few miles above Grafton, above its mouth, samples analyzed as collected from points in the Mississippi river at Alton and Grafton, from the analytical data obtained from samples in the Missouri river. I have done that.

Q. Well, will you tell me what are the parts of those three rivers making up the channel of the Mississippi river at the Chain of Rocks?

A. It is impossible to make these approximations without carefully studying for every case.

Q. You have done it, then?

A. I carefully studied these analytical data. I have done so, yes, sir.

Q. Can you give me the result of your investigation?

A. No, sir. I have not those data at hand. I have done it though, taking the analytical figures.

1620 This is an approximation as applied to the different waters in the channel of the Mississippi river at the Chain of Rocks.

1622 Q. Can you mention any of the substances in the sewage that is discharged into the Drainage canal at Robey street, which are in themselves harmful to health, whether in large or small quantities?

A. Well, the analyses of the samples taken from the Drainage canal at Robey street show certain chemical conditions—the chemical analysis I am referring to now—showed certain chemical conditions of that sewage if confined to the chemical conclusions would not justify me in saying if anybody would drink that water in the Drainage canal at Robey street, after that sewage would have entered it, that it would be injurious to his health, as far as the chemical constituents are concerned, but that leaves out of the question all the bacteriological character of that sewage. There is a question of the potability of that water. It may not show any chemical ingredients that would injure anybody who drinks that water. You can drink sewage—what you call pure sewage, although impure, and there may be no pathogenic bacteria in that sewage and it may not do you any harm.

1623 The chemical analyses alone would not reveal that there are any substances in the sewage discharged into the Drainage canal at Robey street that are dangerous to health.

1624 From the tables that have been prepared on bacteria and introduced in evidence I would draw the conclusion that they disclose pathogenic bacteria as being present in the sewage at Robey street in the Drainage canal. This pathogenic bacteria is coli communis. I consider it in a measure a patho-

genic bacteria. Some intestinal diseases are ascribed to the presence of soli communis.

1625 There is abundant evidence that they are found in the intestinal tracts of many individuals.

Q. Is it not a fact, doctor, and recognized by bacteriologists everywhere that the bacilli coli communis is non-pathogenic?

A. There are some authorities who will call it non-pathogenic because in many individuals it is harmless and then again, there are others who call it pathogenic because it is harmful to others.

Q. Is it not a fact, doctor, that the only way coli communis becomes harmful is when it is inoculated into the blood or into a cut and not harmful when it is taken into the alimentary canal?

A. Well, some authorities assume that standpoint. I am not an expert bacteriologist.

1630 I have not made an accurate scientific estimate of the extent of organic pollution from the Peoria distilleries and glucose works. In my investigations I took into consideration the sewage conditions of Peoria. I gave this pollution which is mentioned some consideration.

1631 The composition of the sewage from the distilleries of Peoria is a certain swill of organic matter that is cast off as refuse.

1632 This material will, in the course of time, undergo some certain chemical changes and will disappear in the run of the river into which it is discharged. I could not tell whether it will oxidize more slowly or more rapidly than household sewage.

Q. If it disappears rapidly, does it disappear more rapidly that household sewage?

A. That I could not tell.

1633 At places where the discharge is in such large quantities as in the Illinois river at Peoria and Pekin, my own eyes

have shown me this swill and refuse from the distilleries. I have seen it anumber of miles down the Illinois river.

1634 Seventeenth annual report of the Health Commissioner of the city of St. Louis introduced. In 1893 by authority of the St. Louis Board of Health, I made analyses of the Illinois river. I started with the collection of three samples on October 11, 1893, at points one, three and five miles above the mouth of the Illinois.

1635 These samples were taken on one occasion only. I did not take any other samples until September, 1899.

Q. Now in the examinations that you made of the waters taken in 1893, what was the condition of the waters of the Illinois river?

A. The results showed the presence of organic matter as evidenced by free and albuminoid ammonia; the presence of nitrites to some extent and the presence of high chlorines, proved contamination of the Illinois river at the mouth.

Q. By sewage pollution?

A. Well, since only one set of samples was taken on that day and I thought that a longer series of collections should be made, I did not pass any definite conclusion at that time on the character of that pollution. In 1899 when I made examinations of the waters of the Illinois river I did draw the conclusion from the large number of samples collected that there was considerable pollution of the Illinois river at Grafton. I stated at that time that the pollution found in 1899 was of a character indicating sewage pollution of the Illinois river. One of the conclusions was that the Illinois river at its mouth was badly polluted during the entire period of investigation, from September, 1899, until the middle of January, 1900, before the opening of the canal.

1637 Q. And in that investigation, did it demonstrate conclusively the character of the pollution as to whether it was sewage or vegetable?

A. My opinion was that it was sewage pollution.

Q. Sewage pollution? A. Yes, sir.

1638 In my investigation in 1893, I found high albuminoid ammonia. I did not determine at that time the albuminoid ammonia in suspension or solution. Free ammonia was comparatively low and the nitrites were quite high in the Illinois at that time. I would not say high, but quite high, the intermediate between low and high. The chlorines were very high. In my examination of 1899, I found the albuminoid ammonia, the free ammonia, the nitrites and the chlorines to be quite high and at times again, low. Albuminoid ammonia I found comparatively high in solution. In suspension I did not find it as high throughout as I did in solution.

1639 I found the albuminoid ammonia in suspension, as compared with the albuminoid ammonia in solution lower that the albuminoid ammonia in solution, but the albuminoid amomnia in suspension was high also aside from being compared with that in solution. Sometimes it would be high but for most of the time the albuminoid ammonia in solution would be higher.

1640 During 1899 I found sometimes the free ammonia low and then again I would find it high. The nitrites the same way. The chlorines I found pretty high. From that analysis I concluded that the Illinois river as it enters the Mississippi was a sewage contaminated stream and the waters were not potable taking into consideration the reports of Prof. Long and Prof. Palmer as to the condition of the entire Illinois river valley. Taking into consideration all the information that I had at hand, I concluded in 1899 that the Illinois river was a sewage polluted stream and was not potable water. I am not acquainted with what is known as Lake Joliet, south of Joliet along the line of the Des Plaines river.

1641 Q. If Lake Joliet was two or three miles in length and from one-half to a mile in width, with a kind of peat bottom bogs, and the waters passing through would disseminate themselves throughout the lake and would only leave a slow

current through the lake, would not that act as a sediment basin for the waters of the Des Plaines river?

A. It would somewhat, and the slower that current would be, the more sedimentation would take place. The faster the current would be, the less the sedimentation would be. A great proportion of the sewage going through a lake of that character would have a tendency to be deposited on the bottom of such lake or morass as it were and fermentative changes would operate in a lake of that character.

1642 Q. If it should appear, doctor, that before getting to Lake Joliet there were quite a number of acres of land over which the waters of the Des Plaines flowed, sedimentation would take place under those conditions the same as it would in the lake, would it not?

A. Yes, if the current were very slow and these low lands would retain any of the sewage that had been during the overflow deposited on the banks. If such conditions would prevail, these fermentative changes would be facilitated somewhat.

Q. While the waters were over the land would sedimentation be the only method of purification?

A. Well, since sedimentation would be one of the material forces of nature, that would bring about various stages of what we call purification. It would operate as a septic tank, for the ordinary conditions that are requisite for a septic tank would prevail there. As I said, slow flow and an abundance of anaerobic bacteria to perform the initial process of purification. I would consider a slow current a current that would have perhaps one-eighth or one-eighth of a mile flow per hour. If the current should be as high as half a mile per hour that would have some effect in facilitating sedimentation.

Q. After the waters left Lake Joliet on their way down the Illinois river, if it should appear that thousands of acres of land were inundated, low-lands, over which the water in its course traversed, what effect would that have upon the prifica-

tion of the sewage laden waters of the Des Plaines river?

A. It would have some effect in distributing the sewage over vast fields there, during the overflow, and if the sewage would have some time there to remain in a quiescent state some fermentative changes would take place in the ordinary process of purification.

1643 If after traversing over these many acres of land that were inundated, it finally empties into the Illinois river, where it continuously overflows the banks of the stream in high water, that condition of purification would be facilitated whenever conditions of inundation of large areas of land would prevail.

Q. Do you know what the conditions are through which the Des Plaines river runs, from Joliet to La Salle, on the Illinois?

A. I am familiar with the conditions somewhat. I have no data or idea of the number of acres of low land between those points that the sewage laden waters of the Drainage canal run over in arriving at La Salle.

Q. Have you any idea or any information of any kind in regard to those conditions?

A. I have nothing definite in that direction.

Q. Don't you think that in order to properly consider this question intelligently, data of that character is essential? A. No, sir.

Q. Isn't it as essential to know in the Illinois river as in the Missouri?

A. It is a matter of analytical investigation as far as the character of that water is concerned, in considering the question of sewage pollution of those rivers, and if the analytical results show high figures at various points along the route that the river is traversing, it would be the most important information, and if found consecutively along the entire route, it would justify general conclusions as to the character of that water chemically.

Q. Wouldn'e it be essential, doctor—as essential in ascertaining the origin of contamination as to whether from vegetable or animal, to know these conditions obtaining in the Illinois river betwen La Salle and Lockport?

A. It is not necessary when the analytical data from the samples taken along the route demonstrate high pollution because the object of the analytical investigation is only to ascertain the character of that water as it flows along that route.

Q. Have you not repeatedly stated in your examina-
1644 tion, doctor, that the anlaytical data, in the absence of knowledge as to the source from whence pollution came, was not sufficient to enable you to determine whether it was sewage or animal pollution?

A. The source, yes, of the pollution as estimated in the analyses of the samples.

Q. And have you not stated that large areas of overflowed land eliminated sewage contamination from waters?

A. I said that it may do so under certain conditions.

Q. And is it not necessary to ascertain whether those conditions exist or not, before drawing a conslusion as to whether the elimination or the presence of the chemical constituents of the water are attributable to animal or vegetable origin?

A. If the analytical results uniformly show high impurities along the route of a river, there are various questions that come into consideration, such as the original source of that pollution, the relative proportion of pollution that might come from tributaries, the relative proportion of pollution that might come from large cities that discharge their sewage into that river. Those questions of primary importance would be considered and in explanation of the origin of the pollution if the chemical analyses enable an approximate distinction between vegetable and animal origin of the organic matter, it would be sufficient to form final conclusions on the character of that water as it traverses the route of the river.

Q. Did you ascertain all those conditions that you have enumerated?

A. In application to what investigation do you mean?

Q. Illinois river?

A. Illinois river, you mean after the opening of the Drainage canal? Q. Yes? A. Yes, sir.

Q. What tributaries of the Illinois river did you investigate for sewage pollution?

1645 I investigated practically all the tributaries that may come into consideration in determining that question. I did not make any analytical investigations of my own because I found such data published by responsible authorities, by Professor Long and Professor Palmer, that could be taken as a fair criterion for the character of those rivers and also a report published by Lyman E. Cooley in 1890.

1646 I understand that there is a large stagnant pool in excess of a mile right under the hill at La Salle. If the Illinois river there would stop its flow completely and enable sedimentation by the stagnant condition of the river there, fermentative changes producing initial purification would certainly be facilitated. I have no idea how many thousands of acres of land in the form of marshes are along the course of the Illinois river. I understand that inundations take place at times of overflow by the Illinois and Des Plaines rivers before the waters get to Peoria. Purification and sedimentation would take place on these overflowed lands the same as would take place along the shore of the Missouri river if conditions were alike in both rivers. Those conditions are, first of all, the chemical character of that water carrying the sewage. The quantity of the sewage in that water in proportion to the quantity of water with which it is mixed, the weather conditions and several other conditions as I have explained them before, which would facilitate the fermentative initial purification process.

1647 That part of the sewage, however, that would remain in the channel would not be similarly affected. That part of the water that would overflow those areas of land would be

come impregnated with vegetable matter. What it would lose in sewage pollution it would gain from vegetable pollution to a certain amount. If that land had vegetation it would necessarily receive accessions from that source. Vegetable pollution would manifest itself in the presence of albuminoid ammonia and also in the color of the water and sometimes as found in the odor of the water. Lake Peoria is located above Peoria. When the waters pass into Lake Peoria after coming from Chicago over vast swamps and marshes, through different lakes and stagnant pools, Lake Peoria would continue the fermentative changes and oxidations of that sewage water more or less dependent upon the size of that lake and dependent upon the question whether there is a flow in that lake, any current carrying the water through the lake rapidly and so forth. I made

1648 no investigation to ascertain the dimensions of Lake Peoria. I don't know how large Lake Peoria is nor how swift the current is. I don't know the source of the Kankakee river. I know of the Kankakee marshes of Illinois, from literature published on the subject. If it should appear that those marshes drain into the Kankakee river, the Kankakee river would carry into the Illinois large quantities of pollution due to vegetable origin at times of very high water in the Kankakee. I deem it a matter of considerable importance to know the number of acres of land in the form of marshes that the waters of the Illinois commingle with and overflow before arriving at Peoria.

1649 I tried to obtain all the information from available data published. I did not get any specific information in regard to the number of acres of land along the Illinois river that was overflowing marshes or farm lands, except that there are general conditions which I familiarized myself with from the literature published on the subject. The dam at Henry is located above Peoria. At times the flow of the Illinois river is very much retarded at that dam as well as at the other four principal dams which are located in the Illinois river. The retarding of

the flow of water at these places serves to elevate the water and back it up stream and overflow the banks of the river and on each side of the river at those places the land is low and thousands of acres of land are inundated by virtue of those dams. Those conditions, in a measure, act as a septic tank for the waters of the Illinois when it is backed up there and held by those dams. I didn't in my examinations endeavor to ascertain in what measure and to what extent purification would take place at those points.

1650 I think I was able to judge from analytical results from the samples taken along the route what effect the dams would have in the ordinary purification processes of the sewage in the water. I think that at times during the year some effect is due to those dams in purifying these waters of the Illinois river to some extent. That effect would be prevalent during the low water stages of the year, after the overflow had taken place, carrying the sewage laden water over those fields. That is, at the low water stage that part of the sewage that would remain on those fields would not be swept back into the river and of course the low water stages then would facilitate the purification processes.

1652 Q. During high water, there is increased dilution with a correspondingly increased current, with a correspondingly greater area of territory inundated, is that true?

A. Yes, sir. These elements may be of value but not essential in drawing a conclusion as to the sanitary character of that water as it flows in the river.

1653 I have not taken into consideration all those conditions.

Q. Would you be able to draw a definite conclusion from the analyses in the absence of any knowledge upon those conditions—a conclusion as to the condition of the water and the source of its contamination, whether vegetable or animal?

A. Yes, as far as that is concerned.

Q. Take the chlorines—could you tell to what the high chlorines would be attributed in the Illinois river if you didn't

know the source from which it was derived, except by the analyses that were made of the waters?

A. These high chlorines and the high ammonias and the high organic matter in general found there, if accompanied by high nitrites would suffice to enable the conclusion that the chlorine there was due to sewage pollution. The conditions of the Illinois are different from the conditions of the Missouri.

Q. Can you tell by the chlorines whether in the Illinois river they come from vegetable or animal origin?

1654 A. Well, that would be impossible for anybody to determine as to the chlorine itself. As chlorine, I cannot tell whether it comes from mineral, vegetable or animal origin. It is not likely that you can have free ammonia, high albuminoid ammonia and high nitrites from vegetable origin. It may be possible. I think it does in exceptional cases, but not as a rule. Those conditions can not obtain in water from animal origin unless accompanied by correspondingly high chlor-

1655 ines. You could have high free ammonia, high albuminoid ammonia and high nitrites with the chlorines attributable to salt beds. You could have that condition as being derived from vegetable origin.

1656 That may be possible in some instances but it would be an exception to the rule.

1661 Q. At what times would these rivers (tributaries of the Illinois) pollute the waters of the Illinois so as to make the waters of the Illinois unpotable.

A. Well, they could do so when the stages of the river, by its tributaries, would be high, because that would sweep out whatever accretions of pollution there might have been on the banks, that would increase the ammonias. It would sweep out the deposited sludge in those rivers and that would enter the rivers. Now this would depend very much upon the character of that pollution, whether of vegetable or animal origin. I speak of pollution in general—not specifying sewage pollution. The general analytical results from those rivers demonstrate that the pollution from those tributaries disappear during the

run of the Illinois river. I think that the Joliet sewage before it would reach the mouth of the Illinois would be purified to the extent that the effect of the original pollution would be of a character that while the water at the mouth of the Illinois would be pure, yet it would it would be in a much better condition than the water at the mouth is, because of the sewage of the drainage canal entering the Des Plaines river.

Q. I am eliminating the drainage canal, doctor. I am taking conditions that are based upon the elimination of the sewage of Chicago? A. Yes, sir.

1662 That would be true of La Salle and the towns located along the river there. If the water of the Illinois river when it reached the city of Peoria would be pure, it would be true that the sewage of the city of Peoria would chemically have undergone changes by the time it reached Grafton to the effect that it would not be noticed in the analytical results found in the water at Grafton, chemically speaking.

Q. Now, doctor, if your statements are properly based upon investigation and if you properly state the conditions of the Illinois river and its tributaries, as to pollution, will you explain to me how it was in 1899, before the opening of the Drainage canal, you reported to the Board of Health of the city of St. Louis, that the waters of the Illinois river at Grafton were contaminated, and not in a potable condition as evidenced here, by the report on file?

A. Because I found the water of the Illinois river above Peoria badly polluted.

1663 My chemical analyses of the samples taken in the Illinois river a few miles above Grafton demonstrated the polluted character of the river at that point and my investigation of analytical data furnished by Prof. Long and Prof. Palmer showed that the Illinois river was badly polluted a few miles above Peoria.

Q. Then if your conclusions are correct that the Illinois river was a badly polluted stream in 1899 throughout, why is it

then that you conclude that the sewage of the cities along the banks and its tributaries do not contaminate the waters of that river at Grafton?

A. Because the Illinois river was badly polluted before it reached Peoria it passes those towns and simply assumes its bed character again. The Illinois river could be badly polluted and yet any pollution from the tributaries and the towns along the Illinois river could be so inappreciable that it would not materially affect the character of that river. The river in its entire course was polluted in 1899.

Q. The sewage of Chicago previous to the opening of the Drainage canal did not enter the Illinois river, did it, or the Des Plaines river?

1664 A. Yes, sir, it did.

Q. Havn't you testified that when the sewage from the Illinois and Michigan canal was pumped into the Des Plaines river that it had been operated upon by conditions such as a septic tank would give and that the sewage had almost disappeared?

A. Yes, I consider that the preliminary stage of purification had been greatly facilitated by the conditions prevailing in the Chicago river and in the Illinois and Michigan canal but I never claimed that it was not sewage any more when it was discharged from the Illinois and Michigan canal into the Des Plaines river and the Illinois river at La Salle. Why, that is still sewage as long as it is not purified in its entirety and has reached the final stage of nitrates. It is my conclusion that the Illinois river was polluted by the sewage from the Illinois and Michigan canal to some extent in 1899 certainly, and the analytical data show that. It manifested itself at Grafton by the bad condition that the water was found to be in at that point.

1665 Previous to the opening of the Drainage canal the amount of sewage entering the Des Plaines river through the Illinois and Michigan canal could not very well be estimated but the chemical analyses can show the presence of char-

acteristic ingredients of sewage pollution that would enable an estimate of the degree of pollution of the water in the Illinois and Michigan canal with the sewage. An accurate count has been kept and published of the number of gallons pumped from the south fork of the Chicago river into the Illinois and Michigan canal at Bridgeport. The amount that is pumped each day indicates the amount of sewage that enters the Illinois and Michigan canal. It varies considerably, sometimes it may be 10,000 or 12,000 cubic feet per minute and other times, it may be 20,000 and 30,000 and as much as 40,000 cubic feet per minute.

1666 I could not tell how that compares with the amount of sewage from Kansas City, Missouri, at that time.

1667 My opinion, based upon my knowledge of the conditions prevailing in the Illinois river prior to the opening of the Drainage canal is that the sewage from the Illinois and Michigan canal does not disappear by the time it gets to Grafton. I never took any samples of Illinois river water at Peoria before the opening of the Drainage canal.

1668 The reason I am able to express an opinion on the matter is because there are data of responsible investigators at hand showing the chemical character of the Illinois river at Peoria that enable conclusions.

Q. Why is it that the sewage from Chicago prior to the opening of the Drainage canal would purify itself in running 350 odd miles when the sewage from Peoria does in going less than 150 miles?

A. First of all, I don't concede that the sewage from Peoria purifies itself from a general hygienic standpoint during that distance. I only assert that the effects of the pollution of the Illinois river from the sewage of Peoria are not discernable in the chemical analyses as far as chemistry is concerned, from the samples collected at Grafton several miles above the mouth of the Illinois—as far as chemistry is concerned.

Q. If that is true, doctor, what you have just stated, can

you determine whether the sewage which you found at Grafton is Chicago sewage or sewage from Peoria?

A. It can only be ascertained what the effect of discharge of Peoria sewage into the Illinois river is on the sanitary character of the Illinois river, that is the only thing that can be ascertained.

The conclusion is justified that since the chemical analysis of samples of water taken at a point a few miles above
1669 Peoria, the chemical character shows certain conditions of the Illinois river at that point, that after the introduction of the Peoria sewage into the Illinois river, before the Illinois river reaches Grafton, the chemical character of the water at Grafton is of a certain character, comparing that character with the character found in the water above Peoria, the conclusion is justified that the effect of the Peoria sewage on the Illinois river has disappeared, and the general pollution of the Illinois river as established above Peoria continues in a measure to the mouth.

Q. Can you determine by your analysis at Grafton, if what you stated before is true—Chicago as distinct from Peoria sewage?

A. That could not be done. Nobody could do that.

Q. That includes yourself, does it?

A. Yes, sir. Hypothetically I would say that since the Illinois river showed such high pollution during its route from La Salle to Peoria, and this high pollution being found throughout all our investigations, that while the absence of sewage from Peoria might reduce that figure, it is my opinion now—hypothetically—that the pollution of the Illinois river, without the addition of the pollution from Peoria, would prevail to a sufficient extent to still render that water as found a few miles above the mouth of the Illinois, unpotable.

Q. Would it be to such an extent to the same degree under those conditions as it would if supplemented by the sewage of Peoria?

A. Well, I have already answered that question; that I said that while there might be less of pollution noticeable at the mouth of the Illinois river in the absence of pollution from Peoria, that still the pollution of the upper Illinois, before it reaches Peoria being uniformly high, as found throughout all our investigations, this pollution would still prevail to a certain extent at the mouth of the Illinois, rendering the water of the Illinois river at its mouth unpotable. As I have

1671 already testified, if the Illinois river water before it reached Peoria would be pure chemically the effect of the pollution of Peoria sewage in the Illinois river would not be discernible at Grafton. From the examinations and the sources of information I had at hand I concluded that the Illinois river was a polluted stream prior to the opening of the drainage canal. I atrtibated that pollution to sewage pollution from the Illinois and Michigan canal. I did not investigate whether the tributaries of the Illinois contribute any pollution for 1899. I had no data to that effect.

1672 As I have testified before, when the stages of the tributaries are low, the pollution from these tributaries is inappreciable. When they are high, it may be possible that at times—when they are very high, and they sweep out considerable pollution that has accumulated in the course of the tributaries—that that pollution may have some influence in increasing the pollution found at Grafton. I do not know, off-hand, whether the sewage unconverted that emptied into the Des Plaines river from the Illinois and Michigan canal exceeded in volume and quantity all the other sewage from the tributaries and from the cities along the banks of the Illinois river between Lockport and Grafton.

1673 I think that the sewage coming from the Illinois and Michigan canal would be larger than from the tributaries and from those small cities along the route.

1680 The addition of water does not increase or decrease the quantity of polluting substance in that water.

1682 At times of low stage of the Ilinois river the sewage that

entered the Des Plaines river from Chicago prior to the opening of the Illinois and Michigan canal was greater than the sewage from all of the tributaries of the Illinois river and the cities that were built upon its banks from Lockport to Grafton. I could not state how much greater, because I would have to consult the original data.

1683 I have made such calculations several years ago in preparing my report on the investigations in question here. I do not recollect how much sewage I gave to Peoria. The sewage from the city of Chicago at that time I figured hypothetically from publications by authorities who had expressed opinions on the quantity of sewage from Chicago.

Q. I asked you if any sewage from Chicago entered the Illinois and Michigan canal except at the pumping works at Bridgeport?

A. To my knowledge at this moment, only at Bridgeport.

1684 It is a fact that not a drop of the sewage from the Chicago river enters the Illinois and Michigan canal except what is pumped in there. At times of low river stages I say that exceeds the sewage polluted water that comes from all the cities lying on the tributaries of the Ilinois river which empty into the Illinois river.

1685 I have not made an estimate of the cause of the effect of the sewage of Springfield, Illinois, on the Sangamon river. It wasn't necessary. I based my estimate as to the amount of sewage draining into the Illinois river from Joliet, on the water supply of the city of Joliet. My estimate of Pekin I made upon chemical analyses of samples of the water taken above and below Pekin. The quantity of sewage from Peoria I based upon the water supply; that was to include all

1686 the sewage from the city of Peoria. I do not know directly how many tons of sewage or refuse is drained into the Illinois river every day by the distilleries of

1687 Peoria. Prior to the opening of the drainage canal the Illinois river was a polluted stream. In 1899 there was

somewhat of an epidemic of typhoid fever in St. Louis. There were 482 cases reported in November, 1899.

1688 The only other month of any year in which the number of typhoid fever cases exceeded that of November, 1899, was in 1892. I have not got the data at hand now, but it is my impression that it was October or November, 1892.

1689 No reason has been found for explaining the presence of typhoid in 1899 in St. Louis, to my knowledge. That was before the opening of the drainage canal. Since the opening of the drainage canal we have not had as many as 482 cases of typhoid in St. Louis in any one month.

Q. Then the conditions in the public health of the city of St. Louis since the opening of the drainage canal has never reached the point in typhoid that occurred for any one month in 1899. Is that correct?

A. If based upon the estimate of one month you are right. The data I get my information from, that the Kaw river runs through a salt country is "Mineral resources of the United States. Calendar year 1887. United States Geological Survey." A tabular presentation of salt deposits in the United States, published in this government publication, page 732, in the column, "Mineralogical Name."

1690 Several tributaries of the Kaw river, as well as the Kaw river itself—the Kaw river being 300 miles long—drain through several of these counties which are mentioned here as having salt deposits. I have no other sources of information on that subject from literature.

1691 (Wtiness states what potable water consists of.)

1693 (What is potable water, or not, depends upon public health statistics.) If the public health statistics show that the water does not have any injurious effect upon the public health, such water can be considered permissible.

1694 DR. WILLIAM C. TEICHMANN, re-direct examination by Mr. Jeffries: Information I have, aside from literature and geological reports, that leads me to believe that the Kaw river runs through salt laden territory consists of the results of

chemical analyses made of samples of water collected from the Kaw river. Assuming that the waters of the Illinois river have been condemned as unpotable; that the immediate tributaries of the river have likewise been condemned as unpotable and assuming the fact that the effect of the waters of the Illinois river on the Mississippi at their junction, or at any point below their junction did not render the Mississippi unpotable prior
1695 to the opening of the canal, the effect of the opening of the canal carrying the Chicago sewage into the Illinois river, upon the Mississippi river water, from my chemical analyses, was a polluting effect and rendered it unpotable.

RE-CROSS EXAMINATION by Mr. Todd:

If water is unpotable the addition of additional sewage will render it more unpotable. The increased pollution caused by the entrance of the Drainage canal into the Illinois river would, of course, have an increased effect on the public health of such community as would use that water for a water supply.
1696 Q. If the people thought that they wanted to use that water and did use it, it would be potable for all practical purposes, would it not?

A. You mean after the increased pollution? Yes, sir.

RE-DIRECT EXAMINATION by Mr. Woerner:

I meant, in answer to the last question asked by Mr. Todd that the potability of the water could only be judged by its effect on the public health. I determine the potability by chemical analyses and a general consideration of the analyses from a chemical and bacteriological standpoint. That is a theoretical way. The practical way would be to judge its effect on the public health.

Q. Has the people's judgment anything to do with the potability of water?

A. Well, the experience of the people in drinking the water may enable them to form an opinion.
1697 A chemist without knowledge of local conditions from analyses can not pass upon the potability of water in streams.

PROF. EDWARD H. KEISER, resumed the stand for further direct-examination by Mr. Jeffries:

1698 I have made an examination from data furnished me by the Board of Health of St. Louis of the condition of the water supply of St. Louis subsequent and prior to the opening of the Drainage canal. In the first place I tabulated all the analyses that were made of the waters of St. Louis prior to the opening of the Drainage canal and I find that the records go back to the year 1894.

1699 (Gives results of analyses made prior to the opening of canal.) Comparing these averages obtained in different years, we see that there are but very slight changes in the character of the water supply at St. Louis. The free ammonia ranged between .019 and .063 parts per million. The nitrites varied from .002 to .005; the albuminoid ammonia from .310 to 1.033, and the nitrates were practically constant. The maximum value for free ammonia before the water of the Drainage canal reached St. Louis was .138 on January 21, 1900, and for nitrites the maximum value was .01 on the same day. These analyses that are recorded prior to the opening of the canal show that the water was comparatively stable, and that it was not an unwholesome water compared with its present con-

1700 dition. (Witness gives results after opening of canal.)

1701 A portion of this great increase in free ammonia and nitrites noticed in February and March, 1900, may have been due to the fact that in the winter months, impurities are usually found to run higher than in spring and summer. (Witness reads table showing results for free ammonia, nitrites, albuminoid ammonia, nitrates and chlorine for various months in 1900 and 1901.)

1702 Comparing the average results for this table with the average results before the opening of the canal, we see that there has been a very decided increase in each of these forms of nitrogen and that the chemical analyses show a permanent pollution of the water.

MR. JOHNS: I move to exclude the entire answer of the witness to the last interrogatory as argumentative.

In looking over the statistics of the Health Department of the city of St. Louis I found 11 analyses of water of the Missouri river at a point above the mouth of the stream, are on record.

MR. JOHNS: I object to the announcing of results of those analyses and the average of them, on the ground that it is all of record, as testified to by the witness.

1703 Witness gives table of average results of analyses of Missouri river water made by city chemist until October 10, 1900, and also during period October 1, 1901 to November 30, 1901.

MR. JOHNS: Same objection.

Comparing these averages now, with the averages of analyses before February 1, 1900, we see that there is but a

1704 slight difference in the average condition of the Missouri river during these two periods. In other words, the Missouri river during the period of September 2, 1899 to November, 1901, has undergone no permanent change in its sanitary character. We see from these that while St. Louis water had undergone a marked deterioration, the Missouri river water had remained unchanged. (A reference to these tables will show that the Missouri river did change, and that there was not much of a change in the Mississippi water at the intake.) It is true that in the winter months the impurities in this river (the Missouri) are higher than in the summer. This is true of all streams, but we see that in the fall of 1901 the water had again returned to its former condition. These results show then, that the increase of impurities in the St. Louis water did not come from the Missouri river.

MR. JOHNS: I move to strike out the entire answer as an argument.

1705 Witness reads average of analyses made of Mississippi river water by health department, of 17 samples collected at Hartford, one mile above mouth of Missouri river. Samples were collected between August 3, 1899 and December 4, 1899. Also averages for same point from daily analyses of samples taken from January 23, 1900 to October 10, 1900, and from October 1 to November 30, 1901. (Witness averages both series after the opening of the canal. A reference to the results on pag 1705 will show that the average for 1901, after the canal had been opened a year, are much lower than right after opening of canal.)

Comparing these results with the average condition of the Mississippi river at the same point before the opening of the canal we see that there has been a permanent increase of the pollution of the water.

1706 The water of the Mississippi, like that of the St. Louis intake, has been very materially inferior in sanitary quality since February, 1900, and further, these analyses show that since the St. Louis water is a mixture of the water of the Missouri and Mississippi, the increased impurities of the St. Louis water must have come from the Mississippi river and not from the Missouri river.

MR. JOHNS: I move to strike out the latter part of the answer as an argument.

Between September 6, 1899 and January 17, 1900, 18 samples were collected from the Mississippi river at a point above the mouth of the Illinois river. Daily analyses were made from January 23, 1900 to October 10, 1900, and from October 1, 1901 to November 30, 1901. (Witness gives results of these examinations.)

Comparing these with the results as given, we see that

1707 the Mississippi river above the mouth of the Illinois, while higher in impurities in the winter months, returned in the fall of 1901 to a condition very similar to that which it was in 1899. Plainly, then, the upper Mississippi river is not the source of the impurities that pollute St. Louis water.

19 samples of water of the Illinois river from a point 3 miles above Grafton we re-collected and analyzed by the city chemist at intervals between September 6, 1899 and January 17, 1900. (Witness gives average values.)

THESE RESULTS SHOW THAT AT THIS TIME THE WATER WAS BADLY POLLUTED AND NOT FIT FOR DRINKING ACCORDING TO ACCEPTED STANDARDS. (This was before opening of canal.) From January 23 to October 10, 1900, averages were as follows (see 1707). For October and November, 1901, the averages were as follows (see 1707.)

1708 (Witness then takes averages for both series taken after opening of canal and compares with one series taken before opening.) We see from these that for the ten months since the opening of the Drainage canal there was an increase in free ammonia of nearly 27 per cent and of nitrites 167 per cent. We can only conclude from these figures that after the canal was opened there was a much larger quantity of sewage undergoing putrefactive changes than before 1901. The analyses have shown that both the Missouri river and the Mississippi river above the Illinois have undergone no permanent change but the Illinois river has been rendered more impure as a result of the opening of the Drainage canal. (A proper comparison would be the results obtained prior to opening of canal with the period of October and November, 1901. During the year 1900 the accumulation of sewage was being carried through the canal—this sewage having accumulated before the canal was opened. Such a comparison would be as follows:

From September 6, 1899 to January 17, 1900: Free ammonia, .215; nitrites, .012; albuminoid ammonia, .553; nitrates, 3; chlorine, 25.0.

For October and November, 1901: Free ammonia, .110; nitrites, .043; albuminoid ammonia, .373; nitrates, 1.71; chlorine, 21.0.

This comparison shows less free ammonia, more nitrites, less albuminoid ammonia, more nitrates and less chlorines in the

samples prior to opening of canal than after opening of same. Increased nitrates means an advanced state of purification. Therefore the water is much better after the opening of the canal than it was before with the exception of higher nitrites.)

There were no analyses of the water of the Illinois river at points above Grafton made by the city chemist before the opening of the canal. But from January 23, 1900 to October 10 of the same year, daily samples were taken at a point three miles above Peoria and occasional samples at Joliet and at Lockport. These analyses show that as we ascend the river from Grafton
1709 to Chicago, the water becomes steadily more and more impure. (See average results of analyses at Grafton, Peoria, Joliet, I. & M. canal, Drainage canal, Lockport, Bear Trap dam and Lake Michigan.

1710 Q. Now, what conclusions do thes results show, or lead you to?

MR. JOHNS: I object to the question, as the conclusions have already been testified to and are not, at any rate, competent evidence.

A. We see that the entire Illinois river is in a highly polluted condition. Going down to Grafton, we find that the free ammonia has fallen, but still is far from being in a condition fit for drinking. We see that the oxidation and self-purification processes become very slow as the concentration of the sewage is diminished, and for the same reason we find these impurities in the water of the Mississippi and the water of the St. Louis water works.

MR. JOHNS: I move to exclude the answer as an argument.

(Comparisons shold be made of the average results shown as testified to by this witness from page 1697 to page 1710.)

CROSS-EXAMINATION by Mr. Johns:

1711 As to these samples taken in 1903 and 1904, I have no knowledge as to how they were taken or analyzed except as stated in the report of the Water Commissioner of St. Louis for 1894, page 418. The samples of water referred to in Ap-

pendix I, annual report of the Water Commissioner for year ending 1894 were taken at St. Louis intake, but I don't know what time elapsed after the taking until they were analyzed. I do not regard the St. Louis intake the same thing as the distributing well, but the water is very much the same. The samples upon this paper (appendix) which I enclose in pencil mark, are from the distributing well and from the clear
1712 wells. As to any of these samples in the paper described in Group D and Group C, I cannot tell at what time they were taken either from the distributing well or from the clear wells, or how long a time elapsed until they were analyzed after they were taken. I do not know anything personally in reference to the manner in which those samples were kept or the plan by whcih they were analyzed, except what I have read in that report. In reading of these results I do not state the amount of oxygen consumed, simply to make the report concise and not to overburden the report with the table of figures. There was a statement of total solids as to those samples of May 2, 1893, to January 24, 1894, in group D, and from April 14, 1893, to January 24, 1894, in group C. I did not state the solids, simply because it would throw very little light on the sanitary condition of the water. I regard the question of solids
1713 in solution as having very little to do with the potability of the water. There were no statements in the report of chlorines. I would be able to give an opinion as to the sanitary condition of the water without a knowledge of the chlorine. In order to determine the potability of water there should be taken into consideration the chlorines; the oxygen consumed is not always taken into consideration; it assists in form-
1715 ing an opinion. I have no personal knowledge of the samples taken in 1892 to 1904, nor of those taken from September 9, 1899, to January 22, 1900. I have taken the figures from the tables furnished by the city chemist. I do not
1719 know anything personally as to the eleven analysis of water taken from the Missouri river above its mouth from September 2, 1899, to December 4, 1899. I did not give the

oxygen consumed nor the chlorines because it would have lengthened this statement very much. The chlorine is not of

any importance in the Missouri river, because the Mis-
1720 souri river is highly charged with chlorides which is of mineral origin. I have no knowledge of that, only in so far as the analyses show this water comes from the Kaw river. I have no personal knowledge as to the Kaw river. The results as to that water enable me to form an opinion that it is a fair drinking water—not above suspicion, but still it is drinkable. I come to that conclusion without reference to the solids

in solution or suspension or chlorine or oxygen con-
1721 sumed.

Q. Referring to the sanitary condition of the Mississippi river between August 3, 1899, and December 4, 1899, having free ammonia, .107; nitrites, .004; albuminoid ammonia, .622; nitrates, .5, is that water potable?

A. I should say that was unsanitary water and water that had reached the limit. It shows so much impurity in that water that it ought not to be used for drinking purposes.

Q. Would you consider water having the following parts, namely: Free ammonia, .107; nitrites, .004; albuminoid ammonia, 622, and nitrates, .5, a potable water? A. No, sir.

Q. Now, that was the average condition of the Mississippi river as given in your tables, before the opening of the canal?

A. Yes, at a point above where it mixes with the Missouri. As a chemist and without reference to this ques-
1722 tion, if I had been called upon to analyze a sample of Missouri river water, not knowing that it was Missouri river water, considering the high chlorine in that sample, I would have been inclined to condemn that water as unpotable.

RE-DIRECT EXAMINATION by Mr. Jeffries:

1725 These (indicating paper) are the printed analyses of the water taken from the distributing well and the settling basin of the St. Louis waterworks in 1893.

1726 This paper is from the annual report of the Water Com-

missioner for the year ending April, 1894. The system used in making this examination is stated on the next page in the report. I have read the methods described in this report, and they are the usual standard methods used in analyzing water.

(Page offered as complainant's Exhibit 36.)

MR. JOHNS: I object to the paper with the proposed addition, as it is not a public record and not such a publication in any event as becomes competent evidence.

The first one of these two papers (indicating) give the result of twenty-one analyses of samples of St. Louis water, made from December 15, 1892, to April 20, 1894, in the chemical laboratory of Washington University. That was tap water. (Offered in evidence as complainant's exhibit 37.)

MR. JOHNS: Same objection as made to exhibit 36.

1728 This sheet contains results of daily analyses of water from the Missouri river at Fort Bellefontaine from January 23, 1900, to February 1, 1900. They were made under my direction in the chemical library of Washington Uni-

1729 versity. (Offered in evidence as complainant's Exhibit 38.)

MR. JOHNS: Same objection as made to Exhibit 36. These twenty-eight sheets of paper (indicating) contained the records of analyses made by the city chemist of St. Louis of samples of water taken in the Misouri river at a point above its mouth in 1899, 1900 and 1901, and at the intake tower, Mississippi river, at Hartford, Mississippi river at a point above Grafton; Illinois river at a point above Grafton, all the above for the years 1899, 1900 and 1901, and for the Illinois river at a point three miles above Peoria, at Lockport and Joliet, in the years 1900 and 1901, and of the water of the drainage canal in 1900, and of the Illinois and Michigan canal in 1900, and of Lake Michigan in 1901. Some are the daily analyses and the weeklies have been added on the bottom, and some are the

1730 weekly averages. Mr. Miller and Mr. Getz, together with the city chemist, prepared them. (Offered in evidence as com-

plainant's Exhibit 39.) The evidence which I gave this morning was based on complainant's exhibits from 36 to 39, inclusive. The averages to which I testified this morning were calculated from the data contained in those tables. The
1731 water analyzed within the days mentioned in Exhibit 37 came from a place known as Bissell's Point, before the
1732 removal of the intake to the present location at the Chain of Rocks. I think this water which was analyzed had passed through the settling basins. I am not certain, because I was not a resident of St. Louis at that time. As to the derivation or character of the samples of water out of which the results in Exhibit 37 are tabulated, I know nothing.

J. L. VAN ORNUM, examination by Mr. Jeffries:

1733 Live in St. Louis; am professor of civil engineering at Washington University at present. Graduated in 1888 at University of Wisconsin. In March, 1903, I made in-
1734 vestigations to determine the time it will take for water to flow from Chicago through the drainage canal, the Des Plaines river and the Illinois river and the Mississippi to the water works intake at St. Louis. Investigation was intended to be divided into three sections, one from Chicago to Peoria, another from Peoria to Grafton, and a short and third section from Grafton to the water works intake. The character of the weather and the conditions of the rivers concerning drift-wood made it impossible to follow the floats except during the daytime. The floats were taken out of the water during the night, and their progress was followed and watched from the point where they were taken out the day before continuously during the day until they were taken out again.

1735 The floats used were what is technically known as submerged floats—that is to say, a lower portion consisting of curved vanes so that in whatever position the vanes turned there shall be a considerable area exposed to the force of the current. This is connected by as light a chain as is practicable, to a portion floating on the surface of the water, which offers buoyancy enough to cause the whole affair to float.

1736 The submerge dportion below the surface was one foot, two feet and three feet and those used on the Mississippi this distance were regulated to be about two, four and six feet respectively. The work was first begun on Saturday, March 14, 1903.

1737 I had personal knowledge as to the results I am about to testify to—as to a part of them. I followed some of these floats myself. Others were reported to me by the parties who did follow them.

MR. TODD: Now I want to interpose an objection to the testimony of this witness in regard to all the other floats that were followed by other parties than the witness himself as being incompetent. I learned from the field notes submitted to me and verbal reports given by the observers that on March 15, the party starting in the Drainage canal placed the floats in that canal at Western street bridge following them on that day to the C. & C. T. bridge during a time of 7 hours and 59 minutes. The floats were left in the water during the night and it was the intention to overtake them in the morning but before they were overtaken it was found that these floats had been removed from the canal. It was, therefore, necessary to resume the observations over that same distance of the canal which had been covered by the floats during the night.

1738 The time consumed was a total of 33 hours and 46 minutes from Western street bridge to the Bear Trap dam at Lockport. These floats were not started at Robey street. This omitted distance is about 2,800 feet and we should add about 40 minutes to the total time above given, which would probably make the time from the south branch of the Chicago river to the Bear Trap dam as about 34 hours and 26 minutes. The gauge at the Bear Trap dam when this point was reached read minus 2.3 feet, and the depth of water flowing over the dam was 4.4 feet. This is said to correspond to the discharge of 295,000 cubic feet per minute, or about a normal flow.

1739 The time from the Bear Trap dam from Joliet was observed to be 2 hours and 15 minutes. On the 17th, the ob-

servations were carried from Joliet to a point marked by a flag on the bank, two miles above a certain place where they stopped over night. The time here was 3 hours and 36 minutes. On March 18, the floats were followed from this same point to another marked point, one mile above the DuPage river, the time being 3 hours and 6 minutes. At about this point practically all the floats which were made and which were of the character I have described, were lost. To provide against the necessity of giving up the observations entirely, temporary floats were devised which were used in connection with those remaining floats of the character with which they were provided, and were run continuously and alongside of them. Fortunately these submerged floats remaining were not lost and it was only from Chillicothe to Peoria that the temporarily devised floats were used entirely. On the 19th the floats were observed from this point one mile below the DuPage river to Morris, during the time of 7 hours and 54 minutes. On the 20th, the time from Morris to Seneca was 5 hours and 2 minutes, and from Seneca to Marseilles, without any interruption at Seneca, 2 hours and 15 minutes. On the 21st, the floats were observed from Marseilles to Utica, the time from Marseilles to Ottawa being 2 hours and 7 minutes. From Ottawa to Utica 3 hours and 36 minutes.

1740 On the 22d, from Utica to a point at Depue, the time from Utica to LaSalle being 2 hours and 28 minutes; from La Salle to Peru 58 minutes; from Peru to Marquette 5 hours and 6 minutes; from Marquette to the point at Depue 1 hour and 1 minute. A total from the Bear Trap dam at Lockport to Peoria of 102 hours and 26 minutes. From Peoria to Pekin, 4 hours and 30 minutes. For clearness, I will say that my personal observation of the floats of this party was only the starting of them.

1741 From Pekin to Kingston, 3 hours and 17 minutes, the total time from Peoria to Grafton, 102 hours and 27 minutes.

1742 I, in person, observed floats in the Mississippi river from the point at Grafton where the observations were discon-

tinued as described, through the Mississippi river to a point opposite the St. Louis waterworks intake. The time from Grafton to Alton was 6 hours and 36 minutes and from Alton to the intake tower, at the Chain of Rocks, 4 hours and 34 minutes. The total time from Grafton to the waterworks intake was 11 hours and 10 minutes. This makes a total time as observed from Lockport opposite the Bear Trap dam to opposite the waterworks intake, at the Chain of Rocks, St. Louis, of 9 full days and 3 minutes and as I have said before, including the 40 minutes calculation, about 34 hours and 26 minutes through the Drainage canal, or a time noticeably less than ten and a half days from the south branch of the Chicago river to opposite the waterworks intake at the Chain of Rocks. These floats of the submerged character that I have described are those ordinarily used by civil engineers to determine the velocity at a certain depth.

1744 The Mississippi was at about half stage, that is the gauge readings at that time indicated the heighth of the river about one-half its extreme flood stage. The reading at Grafton on the morning of the day when these observations were taken, was 16 feet. The reading of the St. Louis gauge on that day was 24.3 feet. The wind on that day was in general up stream, never having a component down stream; sometimes the wind coming partially from one side and sometimes from another—the windings of the stream making the wind vary from one side to the other.

1745 The velocity of the wind varied probably from about 5 to 12 miles an hour. The floats were placed in the lower end of the Illinois in such a way that they spread across the river, one in the center, one about half way from this one to the right bank and one about half way from the center one to the left bank.

1746 That was in the mouth of the Illinois river. As they flowed into the Mississippi they moved closer and closer to the Illinois shore of the Mississippi and in a general way,

from the Illinois river to below the mouth of the Missouri, they were more or less close to the Illinois shore, sometimes in the extreme going to the middle of the Mississippi, but most of the time being within three or four hundred feet of the Illinois shore. At about two miles above the waterworks intake, for instance, the floats were quite close to the Illinois shore, probably about 50 feet from it, but from this point on down to the waterworks intake, the floats rapidly left the Illinois reaching the middle of the Mississippi and finally passing the waterworks intake, between the intake and the Missouri shore—all of them and somewhat closer to the Missouri shore than to the intake. The distance from the Missouri shore to the waterworks intake is about 1,500 feet and from that I judged that the floats passed the intake about 700 feet from the Missouri shore.

CROSS-EXAMINATION by Mr. Johns:

The stage of water in the Des Plaines river is very fluctu-
1747 ating. The guages were read by these engineers as they passed them wherever they saw them, but beyond that I know nothing about it. I have been unable to get such readings. I have no exact knowledge of the stage of the Des Plaines river as to the time that these floats were in the river. The river was high. At the time the floats were placed in it the Illinois river was high—it was very high. The bottom lands and the overflowed land along the Illinois river was very ex-
1748 tensive.

It may be that the river was sometimes four or five miles wide, in very high water, from waterline to waterline. The ordinary banks of the river at all places were overflowed, the water extending out into the bottoms. In the Des Plaines river five floats were put in at one time. They were put in at the same places and at the same time. We had floating down the Des Plaines river, under observation at the same time, five different floats—that is, through a portion of it, but from time to time the floats were lost, so that before reaching the mouth of the Des Plaines river I believe that one or two more had been lost. The plan was to distribute them across the channel por-

tion of the river. By channel I mean that part which is the swiftest moving water, as near as could be judged. I had in the Des Plaines river floats of different lengths, one to three feet. I continued that also in the Illinois river. As a
1749 rule the longer floats were placed in deeper water, in the center of the channel. When these floats were placed in the water on a cross-section of the river I understand that the tendency was towards separation, although there was nothing very marked to be observed in that direction. The stage of river throughout our observations in the Des Plaines and Illinois being in a condition of overflow caused them to rather seek the banks. Quite often it was found that they were aground; then they were released and taken back.

Q. Did those floats in the Des Plaines river keep abreast of each other if they were floating rapidly?

A. That would depend largely upon the wind, sir, whether they would keep abreast of each other or not. In general they would keep abreast of each other.

1750 As to which one would advance more rapidly, that would depend whether the wind was more up stream or more down stream. In general the wind was more than otherwise up stream, or had a component up stream, which would affect the shorter float more and hold it back. I could not say whether the direction of the wind would have a considerable effect upon the direction in which the floats went down the river. The effect would be small compared with the effect of the current, of course, but it would have a certain effect. Of course it was generally noticed that during a half day's or a day's run that the floats would work toward the leeward side of the
1752 river.

It is a fact, as a general observation, that the float nearest the center of the channel traveled most rapidly. The floats nearer the shore were much slower.

1753 Whenever I have mentioned a time here that the float was taken out it was the time of the arrival of the most advanced float at that point. The total time of nine days and

three minutes is the fastest time that these floats made down the Illinois river. I have no knowledge of how rapidly the current flowed at the side or the banks of the Ilinois river, except for one portion between Peoria and Pekin, when I simply observed a very slow current at the side of the banks of the stream. I haven't any doubt it was less than a foot a second and very much less.

Q. So that all your observations have determined is the quickest time of the most swiftly flowing water from Lockport to Grafton?

A. Under conditions existing at the time the observations were made, yes, sir.

Q. Isn't it true that the current of the Illinois river at the time of these observations was very much swifter in its channel than at the ordinary stage of the river?

A. I suppose it is.

Q. Is it not true that it was very much swifter than at the low stage of the river?

A. Undoubtedly.

1754 The Mississippi was at about half its flood stage.

1755 The lowest water known at St. Louis was 2.5 feet below the zero of the St. Louis guage. In a straight piece of river the center of the channel is that part of the river in which the flow is swiftest. If it is curved it is swifter toward the concave bank and sometimes very close to the concave bank.

1756 In general the water on the surface flows slower than that two feet below.

The longest chain I used on a float in the Illinois river was three feet and the shortest was one foot.

1757 In the mississippi river these floats hugged the Illinois shore below the entrance of the Missouri river to two miles above the waterworks intake, then above the intake they started across the river. Ther were only two then. We started with three, but the chain parted and one was lost below Alton. I think from Alton down there were only two. About two miles above the intake both floats were about fifty feet from the Illi-

nois shore. One of the chains to these floats was six feet long and the other four feet.

1758 I am wrong in what I just said. The floats were about fifty feet from the Illinois shore at a point where the Missouri river enters the Mississippi. A mile below this point both floats were three or four hundred feet from the Illinois shore. Two miles below this point the red, No. 5, which is the six-foot float, was 200 feet from the Illinois shore and the four-foot float was 400 feet or thereabouts from the Illinois shore. In passing the upper end of Chouteau's slough, still nearer the water works intake, the four-foot float was 600 feet or thereabouts from the Ilinois shore, and the six-foot float was about 100 feet in the rear and about 100 feet from the Illinois shore, and just below that the six-foot float kept moving still further toward the left, and was about to pass at what is called by river men the chutes —that is a passage to the eastward of the island opposite the intake, and was pulled out of the water and put in again opposite the four-foot float, which had not been disturbed, and about sixty feet to the left of it. That is, sixty feet toward the Illinois shore from the four-foot float. That is below the Madison Point light; and still the six-foot float kept working off toward the left and moving toward those chutes, as they are called, behind the islands, to the east of them, and was pulled out again and put in abreast of the four-foot float about sixty feet toward the Missouri shore—at this time, from it. From that time on they both kept on very closely together, the six-foot float, however, lagging behind, but with reference to the shore they seemed to keep or work toward each other, and crossed opposite the intake at about the same distance from the shore. That is to say, the red was disturbed twice; the six-foot float was disturbed twice between Alton and the water works intake. The four-foot float was not touched.

1759 When I say that the floats were close to the shore at a point where the Missouri river enters the Mississippi I mean that the floats passed the mouth of the Missouri river at Missouri River Point, as it is called on the river, at about

fifty feet from the Illinois shore of the Mississippi river—that is, the left bank of the Mississippi.

1760 The Mississippi at that time was at about a half stage, and so was the Missouri. At the lowest guage I could get on the Missouri on this date the reading was 15 and one-half. This is at Hermann. The high water is 35.6, indicating very much the same thing as the stage of the Mississippi. The Missouri river where it enters the Mississippi was very wide at this stage. The floats kept along very steadily. They were aparently so close to the Ilinois shore that they were not affected at all directly by the inflow of the Missouri river.

1761 I don't know of any dikes in the river along the Ilinois shore oposite the mouth of the Missouri river and below that down toward St. Louis. If there were such dikes they would, to an extent, affect the direction or velocity of the current for such a stage as I have described. The floats passed the intake itself on the west side and between that and the shore.

1762 I took them out immediately below as soon as I could get them after timing them as they passed. Both the floats went over there, one of them, as I have stated, however, being removed and put in again, which destroys any significance that may be attached to it.

I should think it is 5 or 6 miles from the mouth of the Missouri to the Chain of Rocks.

1763 In another mile or two the four foot float was somewhat farther from the Illinois shore—perhaps 600 feet and the six foot float was still closer to the Illinois shore, or about 100 feet from it perhaps. This was at Chouteau's slough, that is about three miles below the mouth of the Missouri river. The Mississippi at that point between its normal banks I think is about three-fourths of a mile wide.

1764 It is practically four miles from Chouteau's slough to the intake, by the course followed by the float. Now below the point where the six foot float was about to go into Chouteau's slough, there is a sand-bar or island. In low or medium

stage it is quite a large island and the general current of the river goes around to the left of the island, as you go down the river. It certainly must be the general current of the river at low water when there is practically no flow here and the course of these floats indicated it to be the case at medium stage.

1765 If the red float had not been interrupted, it would have gone through Chouteau's chute, as the river men call it. I was afraid of it. If it had done so, it might have gone below and to the left as you go down the river, of three other islands or two other islands, between that and the Chain of Rocks. That float might have gone to the left of three islands between Chouteau's slough and the intake, if it had not been interrupted at that time. There was a decided current that way and in order to prevent it going that way, I took it out of the water and placed it in the same channel of the Mississippi.

1766 The general direction of the Mississippi river from Chouteau's slough to the Chain of Rocks is very crooked in that vicinity. Its flow at Chouteau's slough, as I recollect it, is about southwest and from that direction there is a gradual curve until at the Chain of Rocks I believe the Mississippi river flows nearly south.

CROSS EXAMINATION by Mr. Todd:

1767 I did not make any investigation as to the volume of water coming down the Illinois river at the time this ex-
1768 periment was made. At the time these experiments were made, the river was much higher than the average condition of the river. In fact, it was overflowing the low lands. The necessary accompaniment of that fact is that the current was swifter.

1769 Q. If the water was six to ten feet above the crest of the dams at Henry, Copperas Creek, LaGrange and Campsville, at the time you made the experiment that would indicate that there were flood waters in the Illinois river.

A. It is a fact that at the time the experiment was made there was a great amount of flood water in the Illinois
1770 river. My experiments were based upon conditions when the river had fallen. It had passed its crest, the highest water had occurred shortly before the observations were taken. So as a general principle I can say that the length of time occupied and recorded here is probably greater than it would have been if the observations could have been made when the river was at the same stage but still rising. I do not know what
1771 the proportion of water in the channel was to the water in the Illinois river outside of the channel. As far as I
1772 saw the water in the basins beyond the banks of the river, or rather the water in the basins of the overflowed lands had a barely perceptible current. As far as I saw it it was practically in a stagnant slow condition.
1773 From my observations in this experiment I am not able to tell what the velocity of the current would be if the Illinois river was contained within its banks. The condition that I found in the Illinois river does not obtain the year around. I don't suppose it will obtain for a period of six weeks during the year. I have no idea whether it would obtain for three weeks. I presume the experiments I made would apply to the Illinois river for a period not to exceed six weeks throughout the year. The reading on the gauge at Peoria was 19.1 feet. The way to interpret that reading would probably be by stating that the low water reading for Peoria is 2.6 on the same gauge and that the highest water previously on record is 21.9 feet.
1775 My experiment only serves to prove the velocity of the current at a time and under the conditions that existed in the Illinois river at the time that the experiment was made.
1776 The water of the Mississippi from Grafton to the intake at the time of the experiment was what is known as high
1777 water. As to the sand-bar in the Mississippi heretofore testified to, I understand that at low water stages, very little, if any, Mississippi water passes to the left of the same. There is a channel to the left of the sand-bar that were are talk-

ing about in the Mississippi river. The three islands south of the sand-bar were submerged when my observations were taken.

1778 After I left Joliet, some of the floats were lost again, mostly from floating into the woods from the side channels which are full at high water. That indicated that the waters of the river separated wherever there was an opportunity to do so and the current is more or less dissipated and the water went over and submerged the lands.

1779 RE-DIRECT EXAMINATION by Mr. Jeffries:

This chart is a tracing I had made to show the point at, or figures of time of the flow from really the Chicago river to the St. Louis waterworks intake, embodying graphically what was given in the figures this morning. It was prepared by me. The figures, for instance, were taken from tables furnished me by different United States engineering officers. (Said map marked complainant's Exhibit 40.)

1780 MR. TODD: I object to the map being introduced.

1782 RE-DIRECT EXAMINATION, by Mr. Jeffries:

That is a graphic representation of the gauge reading of the Mississippi river at Keokuk, Grafton and at St. Louis during the month of March, 1903, and at Hermann, Missouri, for the Missouri river for the same time. I prepared that from figures furnished to me by the weather bureau and in the case of Keokuk, by the figures furnished directly by the gauge reader.

1783 (Chart offered as complainant's Exhibit 41.)

This is a chart prepared by me showing the gauge readings in the Illinois river during the month of March, 1903, at Peoria, Beardstown and Grafton, Illinois. This was prepared by a table furnished by the weather bureau also. (Offered in evidence as complainant's Exhibit 42.)

MR. TODD: I object to both charts being offered as not competent and not prepared from any data which has been verified and known to be correct.

1784 The wind as it existed during these observations in its effect upon the float was not sufficient to drive it or carry it to the westward of the intake, supposing, of course, that without wind it would have gone to the eastward of the intake. I say it is very evidently the case in the first place, and it must be said that the wind does have an effect on the float, because it reaches the unexposed portion of the float, and the amount of that effect is a matter of computation, depending upon the circumstances existing. (Witness gives details of computation on which he bases his answer.)

1786 If there had been no wind, according to my conclusions, this four-foot float would probably have passed 450 feet to the westward of the intake instead of 800, as it did.

1787 Foat, white, No. 5, on which I wrote my name at the time it was used in the Mississippi river, is the one that passed, as I stated, about 800 feet west of the intake before it was taken out. (Offered in evidence as complainant's Exhibit 43.)

RE-CROSS-EXAMINATION by Mr. Todd:

At the time this experiment was made the water was wavy. I calculated the velocity of the wind simply from being obliged for a great many years to arrive at that from observation only. I did not have an instrument.

1790 The velocity of the wind that I give is an estimate.

RE-CROSS-EXAMINATION by Judge Springer:

1792 When I made these observations I was in a steam launch in the vicinity of the floats all the time. I got the measurements as to the relative distances from the shore of these lines by estimation, by eye and by experience in that class of work a great many years. I had no actual location or measurement. I made only one experiment between Alton and the intake as to the velocity of this float.

1793 The wind was blowing in a general direction from the southeast, that would make the waves move across the current of the river in a northwesterly direction. The force of

the waves, whatever it might have been, would be to crowd the float northwesterly and therefore toward the Missouri shore.

C. V. MERSEREAU: I made observations of the
1794 velocity of the water in the Chicago drainage canal and the Des Plaines river under the direction of Prof. Van Ornum. These observations were begun on Mach 15 and ended on March 26, 1903. For part of the work we used floats similar to the one exhibited here. Part of the time we used a float that was made of a white pine picket, about one and one-eighth of an inch square, on the bottom of which were nailed two pieces of tin, bent at right angles so as to resemble those floats.
1795 About 9 o'clock on March 16 the water guage of the Bear Trap dam at Lockport was 4.4 feet.

CROSS-EXAMINATION by Judge Johns.

1805. The float was in the middle of the current a part of the time. I would put a float in the river and try to put it where I thought the point of maximum flow was. Whenever that float appeared to be working too much to one side I would go out and drop another float oposite to the first one and then let them both run from there and see which was running the fastest, and take up the one which was lagging behind, the object being to keep the float traveling as fast as I could discover current to make them travel. I was taking the fastest float, and if the float began to get slow I put in another one opposite and
1807 ran it.

In the drainage canal I read two guages, one at the Bear Trap dam and the other in the corner of the basin. I think the next guage I got was at Morris. The guage at Morris was 91.25, The next one I read was on the same day at the Seneca Railroad bridge. The guage was 95.0.

1809 I had the reading of the guage about a quarter of a mile above the dam at Marseilles. It was 98 feet even. At the Ottawa bridge the "10" figure was indistinct; it was either 80.6 or 90.6. At the La Salle bridge the reading was 81 feet. The guage on the Peru highway bridge was 14.75. At Henry the guage reader gave me the 1810 guage at 11.8 at seven in the

morning. He gave me the high water of the Thursday or Friday before that at 13.4 feet.

1811 The actual time from Chillicothe to Peoria was 29 hours and 59 minutes. The progress of the floats, even in this high water, through Peoria lake, was very slow. No one float floated along uninterruptedly from Mossville to Peoria.

1813 CROSS-EXAMINATION by Judge Springer:

Q. I desire to learn the velocity of the float in Peoria lake, if you have a note of that, so as to indicte the velocity at that place?

A. I will have to work it out for you definitely; that is, the time here is not continual on account of putting in and taking out the floats. I would have to add the different times in order to give it to you. There was a very decided diffierence in the velocity of the floats in going through the narrows or through the lake.

CROSS-EXAMINATION by Mr. Todd:

1815 The floats were taken out of the water once on an average of every five minutes; that is, one float, that is where I was running five. As a rule the cause was that the float was not following the channel of the river. The country was overflowed and there was a tendency of the floats to leave the river and go out across the point, so that you had to be continually taking up a float that was on the inside and putting it on the other end of the line.

CROSS-EXAMINATION by Judge Springer.

1818 The total time of the float in going from the upper bridge at Peoria to the bridge at the central part of the town, which is approximately three miles, was 5 hours and 49 minutes, which would make one mile in about 1 hour and 56 minutes. It was practically one mile every two hours.

1819 The width of the lake oposite the city of Peoria was wider than when the river is at an ordinary stage. In other words, the river was out of its banks. All the way down from Joliet to Peoria the character of the water was a little turbid.

I think that the water in the river was more turbid than the water in the canal. I think the water that was coming in from the Fox river was rilier than the water in the Illinois—more turbid.

FRANK J. BROWN, examined by Mr. Jeffries:

Employed by the waterworks of St. Louis. Worked on the Illinois river last March to ascertain the velocity of the current of the Illinois river. I started at Peoria and came down as far as Naples.

The total time was 71 hours and 40 minutes from Peoria to Naples.

CROSS EXAMINATION by Judge Johns:

I started the floats about 50 feet apart, at Peoria, on March 14th. In going from Peoria to Pekin I had to take them out of the water, some of them, because they grounded, partly on the right bank of the river and partly on the left. I think it was on the right bank the most, if I remember. The river from Peoria to Pekin is quite tortuous. I think that the one-foot submerged floats made a little the best time. The three-foot was the slowest, except in case of high winds up stream, and if anything they would fall behind, but in an ordinary current or wind, the red floats made the best time. If the wind was high and blowing up stream, the three-foot floats would travel the most rapidly.

The gauge at Peoria, at the starting place was 19. At the highway bridge at Pekin, on the 15th of March, it was 13.6. At the State locks, the same day, 17.5—that is, the Copperas Creek dam. At Havana, March 17th, at the highway bridge, it was 16.9; on March 19th at Beardstown, it was 16.1. At Meredosia, March 21, the gauge was 17 feet, nine and one-half; just below the boat landing at La Grange, 24.50, at the upper end of the locks, and 24.25 at the lower end.

CROSS EXAMINATION by Mr. Todd:

I said that with a very high wind blowing up stream the free-foot submerged float made a little the best time. I think at one time the wind was fully as high as 25 mile an hour.

1826 That is all a pure guess as I had nothing to measure it by.

1827 A ten-mile an hour breeze across stream would not affect the six-foot float at all. I noticed that the white float would make better time when the wind was blowing upstream. When the wind blew up stream the two floats did not go down the stream with uniform regularity.

1828 When the wind was blowing a gale, ten or fifteen miles an hour, I did not take the floats out of the water at any time. When they would get out of the channel or get too near the shore or get aground I would take them out. From Peoria down to Havana I had some trouble with them but it didn't seem to bother me so much after that. I do not know what was the cause of it, unless it would be the wind blowing from the bank driving them over that way. I noticed which way the wind was blowing, the floats always go that way. The floats would always go with the wind across the stream. The wind had a perceptible influence on the floats in going across.

1829 When the wind would come up at a ten-mile an hour gale it would some times be a couple of hours before they would strike the shore. I think that if they were out in the current, ordinarily they would go two or three hours without running ashore.

JOSEPH GIBSON, examined by Mr. Woerner:

1830 Am employed in the Water and Construction Departments. Made observations last March in order to ascertain the rapidity of the current of the Illinois river. I started from Naples, Illinois and went down to Grafton. I was 30 hours and 37 minutes from Naples to Grafton. Started from Naples on March 18th.

CROSS EXAMINATION by Judge Johns:

1832 At Naples the gauge reading equals 18 feet two and one half inches. March 19, Chicago & Alton's draw-bridge, gauge reading 16 feet and 6 inches. Government gauge at Campsville, March 19th reading equals 24.7, that is above the dam. Saturday, March 21st, at Grafton the gauge reading was 17.0.

Sometimes the floats would run into the drifts or drift out on the edge of the bank. When they did so, we would take them out and put them in the current opposite where we took them out as closely as we could.

The wind was mostly upstream. The first day the wind was upstream, mostly from the right bank. The second day it was partly from the right bank. The third day we had a higher wind.

Q. Did they seem to dritf off toward the bank in the direction in which the wind was blowing?

A. Well, I think it had a kind of tendency to draw them over, at times. The river was very high—out all over the bottoms. When there was considerable wind there were waves in the current of the Illinois river, sometimes quite rough.

Q. When the waves struck these floats, it seemed to knock them over in the direction which the waves ran, didn't it, a little?

A. Yes, that had a tendency to work that way somewhat. There was a visible effect of that character. When the wind blows upstream and the floats are floating down-stream, I don't think the wind would have very much effect on them—not the wind I encountered.

THOMAS F. REED: Live in St. Louis. Am rod man in the water department. Took part in observations, the object of which was to determine the velocity of the flow of the Illinois river last March.

I covered from Lockport to Morris and from seven miles above Henry to Chillicothe. Those two portions were assigned to me. I started two floats at the Bear Trap dam on the 16th of March. From Lockport to Joliet, it took me two hours and 15 minutes. It took me 3 hours 35 and one-half minutes to go two miles and a half, about, above Millsdale. It took me 18 hours and 20 minutes to go from Lockport to Morris.

CROSS EXAMINATION by Judge Johns:

1841 At Ninth street bridge at Lockport, the gauge on the bridge read 16.7. On the 18th of March, at the mouth of Jackson creek, I read the gauge 81.55. Three miles below Millsdale 81.1. On the 19th of the month on the E., J. & E. railroad bridge 87.7. The Lacon wagon bridge was 18.7 feet.

1842 The river was very high. The wind caused the floats to move out of the channel. The wind would drive them right into the shore right along. The wind was generally across-stream and up-stream part of the way. The wind would blow the floats towards the shore in the direction the wind was blowing.

1843 On the second section that I was working, the river was very wide and the dams were all submerged with water. The wind had a free sweep. The water was quite rough all the time. The waves ran a foot high and more. When I had to take the floats out they had drifted in the direction in which the waves were running.

1844 L. B. ENGLISH, examined by Mr. Jeffries:

Live in St. Louis, am a law clerk in the city counselor's office of St. Louis.

Q. I will ask you if you have done anything with reference to the collection of typhoid death rates in various cities along the Mississippi to the north of St. Louis, in the last two or three months?

A. Yes, sir. I examined Minneapolis, St. Paul, Dubuque, Des Moines, Keokuk, Burlington, Hannibal, Quincy and Fort Madison. This was done commencing on the 6th of April and extending over a period up to and including April 15th this year.

I went to Minneapolis first.

1845 I examined the records to determine the deaths per month and year from typhoid fever and the total number of deaths.

MR. TODD: I object on the ground that the records are the best evidence and on the additional ground that anything that he might say is here hearsay and is not competent.

I examined the records in the office of the Health Commissioner of Minneapolis to ascertain the deaths from typhoid fever and the total number of deaths from all causes. I have got those by the month beginning with January 1, 1893, up to and including December, 1902.

MR. TODD: I object to the question on the ground that the records are the best evidence and it is incompetent for this witness to testify to what the records disclose. In order to save time, will it be understood that this objection goes to all of this?

GENERAL CROW: Yes, sir, that will be understood to apply to all this class of testimony.

1846 (Witness gives number of deaths from typhoid in Minneapolis for years 1893 to 1902 inclusive.)

1850 On the following day I made a record of the deaths from St. Paul. (Witness gives same statement as to St. Paul.)

1854 I went to Prairie du Chein, but the records were incomplete, and they had only been taking them since the State law was passed requiring the clerk of the city to make them, and he had only been making them a short time. That place has a population of 3,500. Went to Dubuque, Iowa. (Witness gives number of deaths from typhoid in Dubuque by months from 1893 to 1902, inclusive.)

1858 Next is Des Moines, Iowa. (Same testimony.)

1862 From there I went to Burlington, Iowa. (Same testimony.)

1865 From there I went to Fort Madison. The records had only been kept a very short time, and they commenced with the year 1900. In 1900 they had four deaths, in

1866 1901 no deaths from typhoid reported. The law in Iowa is that all deaths must be reported to the city clerk, and he keeps a record of them. It was from this record I got this. From January 1 to March 31, 1903, they had no deaths from typhoid. From there I went to Keokuk, Iowa. (Witness gives number of deaths from typhoid fever by months from 1893 to 1902, inclusive. I collected these figures from the rec-

1870 ords themselves. The next place I went was Quincy. I

made the same character of examination at Quincy as I did at the other points. (Witness gives number of deaths from typhoid fever by months from 1893 to 1902, in-
1874 clusive.) The next point was Hannibal. (Same testimony.)

1878 CROSS-EXAMINATION by Judge Johns:

These records themselves were kept in tabulated form in all the cities with the exception of Fort Madison. They gave the cause of death and age, birthplace and deathplace and burial place, and all those sort of things In each one of those towns when I found those records they had persons and clerks as custodians of those records. In some cities that I took in—two or three places—the records were kept by the city clerk. In larger places they were kept by the health commissioner, but in all these places except Fort Madison they were in the custody of some officer appointed for the purpose of keeping the records.

1879 CROSS-EXAMINATION by Judge Springer:

I did not examine the records at Davenport, Iowa, or at Rock Island, Illinois. Rock Island is a large city. I did not examine the records at Galena. In each instance I took account of the population at the time I took the records—that is, the census of 1900. I found upon some of these records a statement as to the number of cases of typhoid that were treated—that was in one or two places—but they told me it was not accurate, as it depended upon the physicians to report them, and as a rule they were not sufficiently accurate to make any complete record from.

CROSS-EXAMINATION by Mr. Todd:

1880 All I have testified to I have simply got from the inspection of the records, copying from the records at the different places I have indicated.

1881 CROSS-EXAMINATION by Judge Springer:

In the cities of Des Moines, Burlington, Minneapolis and Dubuque I have the certificate of the clerk as to the correctness of those figures.

J. L. VAN ORNUM recalled, examination by Mr. Woerner.

I have taken samples of the waters of the Mississippi and Missouri rivers recently for the purpose of examination. On the 10th and 12th of April samples of water were taken at sections noted on this sheet (referring to map), one secion being just above the confluence of the Missouri and Mississippi rivers in the Mississippi river, another above the same confluence in the Missouri river, another section in the Mississippi river below the confluence of these two rivers, and a fourth one about a thousand feet above the water works intake. These samples were taken for the purpose of sending to Mr. George C. Whipple, at Brooklyn, for turbidity examination. Duplicates of each sample were retained in St. Louis. For distinguishing the samples at the time of taking, a tag was tied about the neck of each bottle, on that tag being a capital letter to distinguish the section as noted here (referring to map), section I being close to the intake and section C also in the Mississippi river below the confluence of the Mississippi and Missouri, section M in the Mississipi above the mouth of the Missouri, and section B in the Missouri river above the confluence. These were all cross sections, locations being kept on each cross-section from 1 to the highest number, No. 1 always being towards the right bank of the river —toward the Missouri shore. The number of samples taken from each cross-section are indicated on this same sheet. There were three points on section B in the Missouri river, and there was one sample taken at a ten-foot depth at each of these three points.

This map that I have in my hands is a correct indication of the number of points at which samples were taken at each location. It shows the current or the direction of the river, of the flow of the respective rivers in so far as it may be indicated on the map. That red line, as near as may be, indicates what may be called the channel line, or the deepest water throughout the length of the Mississippi,

as shown on the sheet. (Map offered in evidence as complainant's Exhibit 44.)

MR. TODD: I object to the introduction of the map, in regard to what the map itself indicates, on the ground that it is not a correct condition that exists in the Mississippi river to-day, as the map was made in 1880, and has been stated by the witness in the other examination as not being correct as of to-day. I object on the further ground that the red line indicating the channel is placed upon the amp by the witness, and there is not sufficient evidence in the record to justify that that

is the channel to-day as indicated by the red line. My
1866 ascertainment of the channel is based upon soundings
marked upon this map at the time it was made by the government officials.

JUDGE SPRINGER: We object to it as not showing the channel at the present time.

MR. TODD: I want to make a further objection. I object to the note that is placed on this map at the northwest corner, and signed J. L. Van Ornum, as being no part of the map.

CROSS-EXAMINATION by Judge Johns:

These samples were taken under my direction. (Witness
states how samples were taken.)
1887 Part of the samples were taken on the 10th of April
and part on the 12th. Section I, for instance, the distance between the various stations numbered from 1 to 12 is 400 feet. Section 1 is 300 feet from the Missouri shore. That distance was ascertained by sextant angle taken between transit placed on shore and the intake tower. We took three samples at station 1, section I, at six inches, ten feet, and I am
not positive whether the lowest was 30 feet now.
1890 Chouteau's slough is this (indicating on map).

Q. Was it at one of those places, where the word "sand" is, that you took out one of the floats and placed it back in the river, to which you testified the other day?

A. Somewhere along there. It was, I think, about a half a mile to the northeast, as I recollect it.

Q. If the float had gone down that chute it would probably never have gone anywhere near the intake?

A. Probably not.

CROSS EXAMINATION by Mr. Todd:

1891 This map, according to the notes placed upon the sheet by the Mississippi River Commission, was made when the stage of water was comparatively low. The stage of the Mississippi at the time I collected these samples was higher. The map was made at stages varying evidently from four feet above to ten feet above the low water stage. My impression is that the stage of water when we took the samples was 15 and 20 feet above the low water stage. The channel at high water is very often more or less different from the location of the channel at low water. The currents of a river are generally increased by high water. They do not run the same in certain places, as far as direction is concerned. High water has a tendency to change the currents in a river, especially where the channel passes from one side of the river to the other.

1893 Q. Is there anything on this map which indicates the direction of the currents at the stage of water that you found at the time you made your experiments?

A. Only in a general way.

1894 The rate of current at these points where samples were taken would be necessary to know, in order to figure the volume of water passing a given point. That I did not escertain. The current flows most rapidly at the top.

1895 It is a fact that in the Mississippi river channel of today might not be the channel of six months hence. I do not know whether the channel indicated here, by the red line on this map, is the true channel of the Mississippi river today. I have no scientific knowledge on the subject of what is the true channel today in the river.

1903 GEORGE CHANDLER WHIPPLE, examined by Mr. Woerner:

I reside in Brooklyn, New York.

1904 My official title is that of biologist and director of Mount Prospect Laboratory of the department of water supply, gas and electricity of the city of New York. I have been in that position since 1897, except that when I began at that time, I was employed by the city of Brooklyn and since then, there has been a consolidation with New York City. (States his

1909 professional training and experience.) I have had occasion to make microscopic examinations of samples of the waters of the Illinois, Mississippi and Missouri river. In October and November, 1901, I made microscopic examinations from, I think it was 136 samples, some from Lake Michigan, Drainage canal, Illinois river, tributaries of the Illinois, Mississippi river abo[illegible] Grafton, Mississippi river at Alton, Missouri river at Bell[illegible]ontaine, Mississippi river at the Chain of Rocks and at the Illinois shore opposite the Chain of Rocks and settling basins of the St. Louis waterworks. These samples were sent to me at Mount Prospect laboratory in Brooklyn by express. They were marked so as to identify their source. They seemed to be in good condition for the purpose of microscopic examination.

1910 I examined all of them microscopically and in some of them I determined the turbidity and color. I examined them microscopically in order to determine the number and character of the microscopic organisms present. Strictly speaking, all very minute organisms may be called microscopic organisms but all water analysis have come to understand by the term "microscopic organisms" those minute forms of life which are too small to be readily identified without the use of a microscope, but which are large enough so that they do not need to be studied by artificial cultures as we study bacteria. For example, the microscopic organisms belong, some of them, to the plant kingdom and some of them, to the animal kingdom, although these low forms of life it is somewhat difficult to draw the distinction between animals and plants. In the water that I received, some of the organisms found might die out during the period of tran-

sit ,others of them might possibly develop during transit while others still would probably remain unchanged.

1911 They would not increase in number neither would they disintegrate to such an extent as to be unrecognizable. I have tabulated the results of the observations and the microscopic examinations which I made and I have with me these tables which contain the results. I have here a table which I have marked table zero, which gives the results of the microscopic examinations made from samples of water said to be collected from Lake Michigan, five of these samples being labeled as coming from the Lake View crib, three as coming from the Carter Harrison crib, and two as coming from the Four Mile crib. At the top of the table is a line giving the number of the sample, and I may explain that the samples as they were received, were given a serial number, and that these numbers in this line refer to those serial numbers. Beneath the line giving the number of the sample, is a line giving the locality from which the sample was collected, and beneath that a line giving the depth in feet at which the samples were collected, and beneath that a line giving the date of collection. Then in vertical columns I have placed at the left the name of the group of organisms found in the sample. In the second vertical column are the names of the genera found, and in the succeeding columns are the numbers of those genera which were found expressed in terms of standard units of organisms per cubic centimeter. Near the bottom there are two lines, one giving the total microscopic organisms, which numbers are the summation of the numbers given in the vertical columns, and then the last line giving the amount of amorphous matter which represents the amount of matter without form, simply, you might say, dirt, almost. Matter which is not recognizable as an organism; also expressed in terms of standard units per cubic centimeter. And I may say that this term "standard unit per cubic centimeter" is designed to show the relative bulk of these organisms present. In some

cases, one standard unit corresponds with one organism. A standard unit as it is used is a unit of superficial area equal to 400 square microns, one micron being equal to 1-1000 of a millimeter. The advantage of using this unit of a standard unit instead of numbers is that the organisms differ in size and it is our intention in these analyses to express, as far as possible, the relative bulk of the different organisms present, in order that one may be compared with another.

1912 What I have just said applies to all of the tables, as I used the same standard and measure.

(Witness gives descriptions of various micro-organisms found in Lake Michigan, as indicated on table zero.)

1913 The total number of microscopic organisms expressed in the usual forms of standard units per cubic centimeter varied fom 576 to 1,656.

1914 The sheet that I now present is known as plate No. 1, and it contains the results of examinations of samples said to be collected from the drainage canal. The first four were marked Paulina Street and the last six were marked Bear Trap Dam, Lockport. The general arrangement of the sheet is similar to that of sheet No. zero. (Witness describes micro-organisms found in these samples.) The total numbers or organisms varied from 644 to 2,750.

1915 Plate No. 2 contains results of six samples from the Des Plaines river at Lockport above the entrance of the drainage canal. It wil be seen by this sheet that the organisms in general were much less numerous than in Lake Michigan or the Chicago drainage canal. The total number of organisms varied from 24 to 126, excepting on November 26, when there were 2,316. Plate No. 3 contains results of examinations from the various tributaries of the Illinois river. It will be seen that these tributaries vary considerably in the number of microscopic organisms found. For instance, the total numbers varied from 20 to 11,296. It will be noticed that the synedra and tabellaria which were so commonly present in the Lake Michi-

gan water and in the water from the Chicago drainage canal are here only sparingly found.

1916 Plate No. 4, samples received from the Illinois river, three miles above Peoria. This sheet represents the results of six examinations. Plate No. 5 is Illinois river at Beardstown.

1917 Plate No. 6 represents results of samples collected from the Illinois river at Grafton, there being seven such analyses reported. Plate No. 7 represents results of seven examinations from samples from the Mississippi river above Grafton. Plate No. 8 shows results of six samples collected from the Mississippi at Alton.

1918 Plate No. 9, five examinations of samples collected from the Missouri river at Fort Bellefontaine. It will be seen that the organisms in the Missouri river were far less numerous than in the Mississippi river. Asterionella and tabellaria, which were observed in Lake Michigan and in the samples from the Illinois river and the Mississippi river at Alton, were not found at this point. Synedra were found.

1919 Table No. 10 represents the results of examinations of seven samples collected from the Mississippi at a point near the Illinois shore opposite the intake. The total number of organisms varied from 1,588 to 8,344. Plate No. 11 represents the results of seven examinations of samples collected at the intake. Synedra were present in three out of the seven samples, and the total number of microscopic organisms varied from 310 to 1,880.

1920 Table No. 12 represents the results of two examinations from samples collected at the settling basins of the St. Louis water works. Plate No. 13 represents results of examinations of twelve samples collected from the Mississippi river at a cross-section just above Alton on November 12, 1901.

1921 Plate No. 14 gives results of microscopic examinations of samples collected from the Mississippi river at a cross-section just above the Chain of Rocks. The arrangement of

these samples in the cross-section from 1 to 11 being from the Missouri shore toward the Illinois shore.

1922 (Charts offered in evidence as complainant's Exhibit No. 46, with sub-numbers 1 to 15, inclusive.

A diatome is a unicellular plant, and perhaps its most important difference from other unicellular plants is the fact that its cell wall is so impregnated with silica that it is practically an indestructible thing. That is, a diatome might be described as a little plant cell made of glass. The living matter lies within this silicious cell, and after the death of the cell the walls of the cell remain just as they appear during life. In fact, they may be considered as fossil remains of a plant, and there are in existence to-day geological deposits which are composed almost entirely of diatomacious cells.

Q. Are they considered more hardy and more likely to survive the voyage from Lake Michigan down the various water courses to the intake at St. Louis than the other microscopic organisms, or not?

A. Yes, sir. These cells being indestructible, or practically so, could be identified after a long passage through the river, and this cell wall being a strong protection to the cell, offers more favorable resistance than many of the microscopic plants, such, for example, as the blue-green algae or the green algae, even.

Q. Where are those diatomes most likely to be found?

A. Diatomes are likely to be found in almost any kind of fresh water, but there are thousands of species of diatomes, and the particular diatomes with which we are concerned in those examinations, namely, asterionella, synedra, melosira, cyclotella, stephanodiscus and the others mentioned, are more commonly found in ponds and lakes and such bodies of water than they are elsewhere. These organisms just enumerated, or these diatomes just enumerated, are not as likely to be found in the waters of running streams, unless these streams are fed from lakes or ponds or similar bodies of water.

1923 Experience has shown that these organisms would not be likely to be found in streams tributary to the Illinois river excepting so far as these streams are fed by lakes or ponds.

MR. TODD: I move to strike out the answer.

It is my opinion that the diatomes in the Illinois river above the point where it enters the Mississippi river at Grafton came partly from Lake Michigan and partly from the tributaries of the Illinois river; that the waters of the Mississippi river from the various points below Grafton came partly from the upper Mississippi, from Lake Michigan and from the tributaries of the Illinois river, my answer being understood as to refer to the diatomes as a class and without reference to particular genera or species.

1924 There was an organism which I will describe as synedra pulchella variety sub-prolongata, which was found at the intake of the waterworks at the Chain of Rocks, and which was found also in the water of Lake Michigan, but was not found in the water of the Missouri river or the water of the upper Mississippi river, or in any of the tributaries of the Ilinois river, unless we consider the Chicago drainage canal as being a tributary.

1925 (Witness reads table representing averages of all examinations made at each point enumerated for the entire period covered by the observations.)

It contains the average results of the number of most important diatomes present at the various places between Lake Michigan and the settling basin of the St. Louis water works, where samples were collected. It gives the names of the diatomes and the average number of each for each place. I notice from this table that certain diatomes are especially characteristic of certain waters. Take the first on the table, synedra; the conclusion I draw from the results shown there is that the sixteen synedra which were found in the intake of the St. Louis water works came not from the Missouri river nor from the Mississippi river at a point above Grafton, but rather from the Illinois river at Grafton, and if we consider that there

1927 were 577 synedra in Lake Michigan, with only an average of 17 per cubic centimeter in all the tributaries of the Illinois river, I should conclude that the chances were that the sixteen synedra found at the intake, or most of them, came from Lake Michigan. As to the next one, the tabellaria, the conclusion I would draw from the table is that in all probability the tabellaria found in the settling basin of the St. Louis water works and at a point in the Mississippi river near the Illinois shore came not from the Missouri river or from the Mississippi river at a point above Grafton, but from Lake Michigan by means of the Illinois river, and not from any of the tributaries of the Illinois. Let us consider the melosira.

1928 The conclusion from the figures shown on the table is that for the most part the melosira found at the intake of the St. Louis water works and at the Mississippi river near the Illinois shore were derived not from the Illinois river or from Lake Michigan or from any of the tributaries of the Illinois, but rather from the Mississippi river above Grafton. Now consider the cyclotella, the conclusion being that these cyclotella found at the intake of the St. Louis waterworks at the Chain of Rocks came for the most part, not from the Missouri river, but from the Mississippi river and the Illinois river, and only to a slight extent from Lake Michigan. The cyclotella found in the Illinois river at Grafton being derived not from Lake Michigan, but from one or more of the tributaries. Now consider the astrionella, the conclusion being that for the

1929 most part the asterionella found at the intake of the St. Louis waterworks and at the Missouri shore, or at the Illinois shore opposite the Chain of Rocks, were derived not at all from the Missouri river, but chiefly from the Mississippi river above Grafton, but in part from the Illinois river and its tributaries and Lake Michigan. Now the stephanodiscus, from the table I conclude that of the stephanodiscus, or that the majority of the stephanodiscus found at the intake of the St. Louis waterworks and at the Illinois shore oposite the Chain of

Rocks were derived not so much from the Missouri river or the Illinois river as from the Mississippi river above Grafton.

The synedra found in Lake Michigan belong to the species pulchella and variety sub prolongata, while the synedra found in the tributaries of the Illinois river were either the synedra lonslotta or the synedra pulchella variety curta. The synedra pulchella are very easily distinguishable from the synedra lonslotta, because of the different shape, while the synedra pulchella, variety sub prolongata differ from the synedra pulchella variety curta in their size; the sub prolongata being in round numbers, twice as large as the variety curta. All three of these forms of synedra are very easily distinguishable under the powers of the microscope used in the examination.

1930 This would enable me to distinguish which came from Lake Michigan and which came from other sources when they were taken from the waters at the intake. I found the synedra pulchella variety sub prolongata at the intake of the St. Louis waterworks I think on November 12, if I recollect the date correctly. So far as all of my examinations show I should say that they came from Lake Michigan. I made a chart of the comparative number of these different diatomes in various sections —that is, those which were most prominent. This chart depicts graphically the results of my investigations. I present first, diagram No. 1, which gives the results of the determinations of synedra pulchella, per cubic centimeter, at the various places between Lake Michigan and the intake of the St. Louis

1931 waterworks. The next diagram is No. 2 and is drawn by the same plan as the preceding and shows the number of tabellaria fanistrata at the points enumerated on the diffenent sections.

1932 The next diagram being No. 3, shows the number of standard units of microscopic organisms actually discharged with the pollution by the various towns between Lake Michigan and noted at the bottom of the diagram, and states the organisms included in the above.

1933 This diagram shows that the organisms were very few in Lake Michigan, and that they were quite numerous in the Chicago Drainage canal and the Illinois river above Grafton, and from the Missouri river at Bellefontaine and that they were found in the Illinois river or rather in the Mississippi river at the Illinois shore opposite the Chain of Rocks and at the intake of the St. Louis waterworks.

The next diagram shows the number of melosira granulata in the Illinois river at Grafton did not exceed 24 per cubic centimeter standard units, and in the Missouri river at Bellefontaine, they did not exceed 60 per cubic centimeter, the quantity being so low they would scarcely appear on this sheet. The results indicate that during the period covered by the investigation there was a gradual decrease in the number in the Mississippi river at Grafton and that this decrease was also noted at Alton in the Mississippi river and at the Illinois shore opposite the Chain of Rocks, and also at the intake of the waterworks at the Chain of Rocks.

Diagram No. 5 shows the number of cyclotella operculata at various points in the Mississippi river and at the Illinois river at Grafton. The note states that during this period the cyclotella operculata did not exceed 60 per cubic centimeter in the Missouri river at Bellefontaine, but the results indicate that during the latter part of November there was an enormous increase in the cyclotella operculata in the Illinois river at Grafton, the numbers being so great it could not be shown upon the scale of this diagram; and that this increase was also noted at Alton at the Illinois shore, Chain of Rocks, and at the intake of the St. Louis waterworks.

Diagram No. 6 shows results of examinations made of samples collected at 12 points in the cross-section across the Mississippi river above Alton. It shows the results of microscopic organisms and it also shows the results of certain turbidity and color observations which I have not yet put in the testimony. The upper line shows the turbidity of the water at the

different stations expressed in terms of the silica standard.

1935 The second section shows the color of the water at the different stations expressed in terms of the platinum cobalt standard.

The next section shows the number of microscopic organisms characteristic of the Mississippi river, indicated by lines of different character, the full line referring to the total organisms; the melosirt being expressed by the dash line, the cyclotella by the dotted line and the stephanodiscus by the dot-dash line.

The last section on the sheet shows the microscopic organisms characteristic of Lake Michigan. The synedra expressed by the full line and the tabellaria expressed by the dash-line. The results show that the turbidity was fairly constant across the stream, but that it was lower on the eastern shore than on the western.

The turbidity of the water means its opacity to light, or its opacity or opposition to the passage of the rays of light and is a measure of the suspended matter present. Observations of turbidity are frequently made instead of determinations of suspended matter because of the much greater convenience of the method. The diagram shows that there was in general a gradual decrease of color from the Missouri shore toward the Illinois shore and that the color was particularly low near the Illinois shore. The diagram also shows that the melosira, which, as has previously been offered in testimony, were especially characteristic of the waters of the Mississippi river above Grafton, decrease generally from the Missouri shore towards the Illinois shore, while the cyclotella, which were found in both the Illinois river and the Mississippi river, but were more abundant in the Mississippi river at the time when the cross-section was made, were fairly constant across the river excepting near the Illinois shore, while the stephanodiscus were nearly uniform across the stream, but showed a slight tendency to decrease toward the Illinois shore.

The syndera which were characteristic of Lake Michigan were not present in samples 1 to 5 and were most abundant in sample 7; while tabellaria, which also was especially characteris of Lake Michigan, were not found in samples 1 to 4, or in samples 7 and 8, but were found in the other samples.

This last diagram is No. 7, and it shows the results of the observations of the samples taken in the cross-section of the Mississippi river about one mile above the Chain of Rocks, and it shows the turbidity of the water at each station, the color at each station, and there is a line showing the comparative abundance of melosira, cyclotella and stephanodiscus organisms which at that time were especially characteristic of the Mississippi river above Grafton, and a line showing the synedra and tabellaria organisms which at that time were especially characteristic of Lake Michigan. These samples were collected on November 10, 1901. These are the turbidity observations shown on this diagram, and indicate a progressive decrease from the Missouri shore towards the Illinois shore, while the color progressively increases from the Missouri shore towards the Illinois shore. The lines at the bottom of the diagram show the progressive increase in the melosira, cyclotella and stephanodiscus, speaking in a general way, from the Missouri shore towards the Illinois shore, while the same is practically true of the synedra, an organism especially characteristic of Lake Michigan. The tabellaria, which was characteristic of Lake Michigan, was not found west of station 7. It will be noticed, however, that all of these organisms which were characteristic of the Mississippi river water were found at

1937 station 1, and that the synedra, which was characteristic of the water of Lake Michigan, was also found at stations 1, 2, 3 and 4. (Diagrams offered in evidence as complainant's Exhibit 47, sub-numbers 1 to 7, inclusive.) I made calculations as to the relative amount of water coming from the Mississippi and Missouri rivers into the intake. I assume, for the purpose of this calculation, that the samples which were collected at the Missouri river at Bellefontaine represented the

character of the water in the Mississippi river, and that the samples which were collected in the Mississippi river at Alton represented the character of the Mississippi river just above the point, or above the point where the Missouri river enters the Mississippi river just above the point or above the point where the Missouri river enters the Mississippi, and I compared the average results of similar organisms found in the water at the intake of St. Louis waterworks. I concluded that on an average 32 per cent of the water which entered the intake of the St. Louis waterworks was considered as Mississippi river water and that 68 per cent of the water was Missouri river water.

1939 I made turbidity observations and observations of color in the samples taken from the two cross-sections, one just above Alton and the other one mile above the Chain of Rocks, to find the relative turbidity of the water across the stream at the different points and the relative color across the stream at the different points. (Witness gives results of turbidity and color of twelve samples in cross-section taken in the Mississippi river above Alton November 12.) When I say that the turbidity of a sample is 18 it means that that sample is just as turbid as it would be if it contained 18 parts per million of what we call silica standard, or 18 parts per million of finely divided silica, which is prepared according to a definite formula.

1940 The relative opaqueness would be arrived at by the turbidity, and the higher the number the greater turbidity, or the greater opaqueness. The color is measured by comparing the sample of water after removing the suspended matter, with arbitrary standards which are varied in color by the addition of different amounts of platinic chloride, and when I say that the color of the water is 34 it means that the color is as dark as an artificial solution which contains 34 parts per million of this platinum salt.

1941 (Witness gives results of examination of eleven sam-

ples in cross-section from the Missouri shore to the Illinois shore, one mile above the Chain of Rocks.

1942 I received some samples from Prof. Van Ornum during the month of April, 1903. They were received at my laboratory in Brooklyn on April 14 and April 16. I received 68 samples. These samples were tagged. I received a letter from Prof. Van Ornum, in which he stated that the capital letter M referred to a cross-section about one-quarter of a mile above the mouth of the Missouri river, across the Mississippi river, and that the serial numbers from 1 to 8 represented stations in that cross-section, beginning with the Missouri shore and running across to the Illinois shore, and stating further that the samples were spaced 200 feet apart, and also that the letter "b" meant that the sample was collected at a depth of ten feet below the surface. Upon each tag there were also figures indicating the temperature of the water in degrees Fahrenheit.

1943 I also received some samples marked "I," thirty-three bottles, with serial numbers from 1 to 12, that referred to a cross-section of the Mississippi above the intake at the Chain of Rocks. The serial numbers from 1 to 12 represented the stations across the river from the Missouri shore towards the Illinois shore, samples being taken 400 feet apart. The small letter "a" meant that the sample was taken at or near the surface. The small letter "b" indicated that the sample was collected at a depth of ten feet, and the small letter "c" that the sample was collected at or near the bottom of the stream.

1944 On April 16 I received three samples marked with a capital "B," with serial numbers from 1 to 3, followed by the small letter "b" in each case. These represented a cross-section of the Missouri river just above its mouth, No. 1 being near the south shore, No. 2 in midstream, and No. 3 near the north shore, also twenty-four samples marked with capital "C," with serial numbers from 1 to 8, and small letters either "a," "b" or "c." These I collected across the Mississippi river below the point where the Missouri river enters into it. Serial num-

bers ran from 1 near the Missouri shore to 8 near the Illinois shore, stations being 200 feet apart.

1945 I examined all the samples for turbidity.

1946 (Gives results of examination of samples "M," "B" and "C.")

1947 (Gives result of sample "I.")

1949 (Witness exhibits 12 bottles of water from complainant's exhibit 45, marked with capital letter "I" and explains method of ascertaining the turbidity of water.)

1950 Sample No. 1 is very much more turbid than sample No. 12 (referring to bottles Nos. 1 to 12 above referred to.)

1951 Comparing these samples as they stand before me, it is evident that there is a rather sudden decrease in the turbidity of the water from the Missouri shore toward the Illinois shore in the first four or five bottles and that from there on toward the Illinois shore, the difference in turbidity is comparatively small. My recollection is that the first sample was taken about 150 feet from the Missouri shore and that succeeding samples were taken at intervals of 400 feet in this cross-section.

1952 I prepared diagrams to show graphically these cross-sections of the rivers according to the samples that were taken by Prof. Van Ornum, that is, for three out of four—sections "I," "M" and "C." This diagram which I hold in my hand represents graphically the results of the turbidity observations made at section "I" already put in evidence, taken from the samples of water furnished me by Prof. Van Ornum in April, 1903, that is, about one-quarter of a mile above the Chain of Rocks. There are three lines upon this diagram, the line represented by the dots and dashes refers to the sample taken just below the surface of the stream, that would be the samples marked with a small letter "a," the full line refers to those samples collected at a depth of 10 feet, marked with small letter "b," the dash line represents samples collected at the bottom, which were marked with a small letter "c." In the last three

samples, the solid line and the dash line were the same, that is, the bottom sample was at a depth of 10 feet.

1953 I should say that the intake tower would lie approximately between stations 4 and 5 shown on this diagram. (Chart offered in evidence as complainant's exhibit 48.)

1954 The next diagram shows the observations made at section C, being a cross-section of the Mississippi river about one mile below the mouth of the Missouri. The diagram is drawn in similar manner to the preceding. (Offered in evidence as complainant's exhibit 49.) The diagram which I hold in my hand graphically represents the results of observations made at section M, being a cross-section of the Mississippi river, at a point about a quarter of a mile above the mouth of the Missouri. (Offered in evidence as complainant's exhibit 50.)

1955 (Charts of water analyses referred to by witnesses Teichmann, Miller, Getz and others, containing 117 pages, offered for identification, to be known as complainant's exhibit 1 for identification.)

CARL UNGAR, examined in chief by Mr. Woerner:

Attorney at law. Resides in St. Louis. Has made investigation as to typhoid statistics of towns in Illinois river valley.

1956 Left St. Louis by instruction of City Law Department on or about April 7th. Visited Springfield and found the records there in poor shape. Only got three years—1900, 1901 and 1903. (Gives number of deaths per year in Springfield.) Next went to Bloomington. (Gives results of examination of records, showing deaths in Bloomington from 1893 to 1902.)

1958 (Statement as to Peoria and Ottawa.)

1959 (Decatur.)

1960 (Joliet.)

1961 (Pekin.) I found the reports very incomplete.

1962 (Elgin and Aurora.) They hadn't any records worth speaking of.

1963 (Havana.) I took what I could get by the year.

1966 WILLIAM H. GETZ, re-called for direct examination by Mr. Jeffries:

This is a table of percentages of the Missouri and Mississippi river water at the intake of the St. Louis waterworks. These calculations are based upon the daily estimation of total solids in samples collected at Bellefontaine, the intake and at Hartford, covering a period from January 23d to October 11, 1900. (Witness examined in regard to complainant's exhibit 1 for identification, stating how they were prepared and what they represented, in order that they may be introduced in evidence.)

1969 CROSS-EXAMINATION by Judge Johns:

On the charts that were made, the gauges were put, but there were no numerical figures put on the sheets that these were taken from. There was no need of the stages of the river for the purpose of assisting in this conclusion. (This exhibit being offered for the purpose of showing the mixture of the water at the intake.) There is nothing on this table of percentages which shows that on the 7th of February when the percentage of Mississippi river water in the intake was 100 and the percentage of the Missouri river water was zero, as to the state of the gauges at that time. Such figures were put on the charts that have been exhibited covering the weekly averages but not in the tables.

1971 These calculations do not depend, in any way, on the stage of the river. Stages of the river may affect the result, but there was no use made of them in the calculations.

1972 GENERAL HAMLIN: I object to the introduction of the table unless complainant offers to follow it up with proof of rain-fall, and so forth, on the lower Illinois river and the Mississippi and Missouri at the time these calculations were made.

GENERAL CROW: At the proper time, we will offer such statistics on the question of rain-fall and water gauges in

the Missouri, Mississippi and Illinois rivers as we think proper to offer.

CROSS-EXAMINATION by Mr. Todd:

The date from which these percentages were figured was taken from the original note-books first and collected on to these charts, or on the tables and then it was taken from there for this special purpose. These figures were taken from the tables marked here as complainant's exhibit 1 for identification.

CROSS-EXAMINATION by Judge Johns:

1973 When I made these figures as to solids, I took them from the Missouri river at Bellefontaine and for the Mississippi at Hartford. I made the calculation for total solids. Well, there is always considerable variation in the total solids as found in the Missouri river at Bellefontaine, and those found in the Mississippi river at Hartford, and the total solids at the intake of the St. Louis waterworks was found to lie between those two, or approximately the same as either one of them, and by taking the difference in the total solids in the two rivers at those places, and interpolating the value of the total solids found at the intake, we find the percentage of the two rivers, which is represented by the mixture.

1974 CROSS-EXAMINATION by Judge Springer:

Now, for the month of January, 1900, I have presented here 25.75 as the average for all the samples we had during that month and that figure represents the average amount of Mississippi river water entering the intake during that period —about seven or eight days. This average amount of water from the Mississippi that entered the intake during those days in January which are here noted simply means an average which I have reached by estimating the total solids which I found in the waters of the two rivers, one at Bellefontaine and the other at Hartford.

1977 Q. The fact that at one time, during one month for instance, the average would be 25.75 and the next month would be 40.67, and for another month 60.29, and so on—they

are variations which can only be explained from different stages of the river and the different conditions of the weather along the line of the rivers above the place where the samples were taken? A. Yes, sir.

RE-DIRECT EXAMINATION by Mr. Jeffries:

Q. Now, Mr. Getz, along the line of the questions propounded to you by Judge Springer, state what effect the fact of a flood in the Missouri river and a comparatively low water stage in the Mississippi river would have with reference to the correctness of arriving at the proportionate amounts or relative amounts of the two waters going into the intake?

A. It would have absolutely no effect.

GEORGE C. WHIPPLE, re-called for further direct examination by Mr. Jeffries:

1978 Have visited the Chain of Rocks and made myself personally familiar with that portion of the waterworks' plant of St. Louis which is located at that point. The approximate distance from the Missouri shore to the intake tower of the waterworks is about 1,500 feet. The intake tower is located a few hundred feet to the west of the channel of the Mississippi river at that point. I mean the center of the channel of the river—that is, the central thread of the main channel of the stream. It is about six miles from the intake tower to the mouth of the Missouri river. The Mississippi river, before it reaches the intake tower curves to the westward.

1979 (Witness explains the general features of the Mississippi river with regard to curves and directions of flow between the mouth of the Missouri and the intake tower, at the Chain of Rocks, as indicated on complainant's exhibit No. 44.)

1980 From my general knowledge of the subject of rivers and the effect of curves upon the currents of those rivers, it is my opinion that this curve which I have described, in the Mississippi river between the mouth of the Missouri river and

the intake of the St. Louis waterworks would tend to allow, or would increase, or would be favorable to the mixture of the waters which come down the Mississippi river and the Missouri river.

1981 Judged from samples I have examined from section B and section M, I should say that the water in the Missouri river is much more muddy than the water in the Mississippi river and that it contains very much larger amounts of suspended matter. I also found that the water of the Mississippi river at Alton was more highly colored than the water of the Missouri river at Bellefontaine.

1982 In using this term I refer not to any substance in suspension but rather to substances in solution. I have observed that the amount of chlorine in the Missouri river was generally higher than that in the Mississippi river above the mouth of the Missouri. From the same sheets—complainant's exhibit 1 for identification, I also observe that ordinarily the amount of alkalinity in the Missouri river at Bellefontaine was higher than that in the waters of the Mississippi above the mouth of the Missouri.

If I should find certain forms of vegetable life which can be distinctly identified by well defined characteristics in the water of the Mississippi river above the mouth of the Missouri, and if at the same time, these organisms were absent from the water of the Missouri river itself, and if at the same time I should find them in the water of the intake tower of the St. Louis waterworks at the Chain of Rocks; it is my judgment that these organisms found at the intake tower of the St. Louis waterworks came from the water of the Mississippi river above the mouth of the Missouri river and that they were borne thither by the water of the Mississippi river above the mouth of the Missouri.

Q. Assuming that at times the water of the Mississippi river above the Missouri contains very little mud, and that the water of the Missouri river at the same time is highly charged with mud and further assuming that the water taken through

the intake tower at the Chain of Rocks, contains an amount of mud intermediate in quantity between those of the two
1983 rivers before they unite?

A. It would be my opinion that the water found at the intake tower of the St. Louis waterworks, at the Chain of Rocks, was not entirely water derived from the Missouri river nor water entirely derived from the Mississippi river above the mouth of the Missouri, but was a mixture of the two waters.

Q. I hand you a table containing a transcript of the quantities of the total solid matter in the Missouri river at Bellefontaine, and the Mississippi river at Hartford and the water at the intake, which is a table read in evidence by witness Getz and ask you to explain the table and state whether or not the results as to the quantity of water of the respective rivers entering the intake at the Chain of Rocks, are determined by that table?

A. In looking over this table, I find that in general the total solids found in the samples at the intake were intermediate in amount between those found in the Mississippi river at Hartford and in the Missouri river at Bellefontaine and it is my opinion that it is possible from the figures given to calculate approximately the relative amounts of the water of the Missouri river and of the Mississippi river above the mouth of the Missouri present in the water at the intake of the St. Louis waterworks. I understand that the percentages obtained in the last two columns were obtained from the information given in the previous columns. Does that sufficiently answer your question, Mr. Jeffries? Q. Yes.

GENERAL HAMLIN: I move to exclude the answer for the reason that the witness did not make the table itself, or the table from which it was made, nor does he undertake to say that he has examined the samples or made analyses of the waters mentioned. His answer is simply to bolster up a table made by some one else and not by him.

1985 It is my opinion that if the figures given in this table represent the total solids in the water of the Mississippi

river at Hartford and the water of the Missouri river at Bellefontaine, and the water of the intake of the St. Louis water works, at the Chain of Rocks, if these figures are accurate representations of the total solids in the samples collected, and if the samples collected fairly represent the waters of the streams at the points named, then the calculations made by using these figures in obtaining the percentage of water of the Missouri river and of the Mississippi river above the mouth of the Missouri, in the water of the intake of the St. Louis water works, are reliable.

1987 My calculations showed from the samples that I examined that the percentage of Mississippi river water which was present at point 4 in section I was about 90 per cent, that the percentage of Mississippi river water at point 5 in the same section was about 97 per cent. (Witness states method of ascertaining these averages, on pages 1986 and 1987.)

1988 Assuming that when the waters of the Mississippi and Missouri unite at that junction, that there is no mingling of the waters with each other as they flow down stream, I should expect to find that in crossing the river from the Missouri shore to the Illinois shore at a point referred to by section "I" on complainant's exhibit 44, that there would be a sharp line of demarcation separating the waters of the Missouri on the west shore from the water of the Mississippi on the east shore. My examinations which I have made have shown that such a sharp line of demarcation existed and that can be illustrated by referring to samples of water collected at 12 points on section "I," numbered 1 to 12, beginning on the Missouri shore.

1989 It is my opinion that the relative percentage of the waters of the Mississippi river and the Missouri river at the intake can be most readily determined from the total solids.

Q. When considering cities having a population of 25,000 or more according to the census of 1890, what percentage of increase to the population naturally resident upon the watershed of the Mississippi, at the Chain of Rocks, is caused by the Sanitary District of Chicago diverting its sewage into the

Illinois river and becoming thereby tributary to the Mississippi?

GENERAL HAMLIN: That is objected to on the ground that it is not a proper basis of estimation upon which to base a proper conclusion as to this subject matter by an expert, and the further objection that the testimony is not relevant to the issue in hearing, made by the bill and answer.

Speaking generally the population is about double.

1990 If you consider the population of cities which have more than 4,000 population situated upon the watersheds of the Missouri, Mississippi and Illinois rivers, above the Chain of Rocks, but not including the population of Chicago, and if we add to this population, the population of Chicago, we should increase the populations as mentioned, by about 63 per cent.

(Objected to by Mr. Hamlin.)

1991 There is this custom among sanitarians, that when it is desired to determine the amount of sewage pollution which exists in a stream at any certain point, to consider the population dwelling upon the watershed above that point in cities which have 4,000 or more inhabitants and for this general reason we take it the country over. It has been found that in general, communities which have more than 4,000 inhabitants are ordinarily supplied with such public improvements as public water supplies and sewerage systems, while, in general, those communities which have less than 4,000 people are not ordinarily so supplied. In making those calculations, I have adopted the same means. It is about 23 miles by river from the mouth of the Missouri to the mouth of the Illinois.

I believe it is possible by analytical means to determine the percentage of the Illinois river water which is present in the Mississippi river at Hartford, for example. I also made such a calculation in order to determine the percentage of Illinois river water at Alton, as well as at Hartford. I made these calculations from the analyses shown upon the sheets which I hold in my hand and which form a part of complain-

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ant's exhibit 1 for identification. (Witness states method pursued in making such calculations.)

GENERAL HAMLIN: I move to exclude the answer as to the results obtained, as they are not expert's statements, but are statements of a fact determined from tables not made by the witness.

From these average figures, I have calculated the percentage of the Illinois river at the five points in the cross-section of the Mississippi river at Alton and at Hartford.

1994 (Witness states results of calculations at Hartford and Alton.)

This is a diagram which shows graphically the results, the average amounts of nitrites and chlorines at the cross-sections at Alton and Hartford, across the Mississippi river, for the period from October 30th to November 4th, from the period of October 30th to November 29th, in the case of the Alton cross-section and from November 4th to November 30th, in the case of the Hartford cross-section. It also gives in the lower portion of the diagram, a graphical illustration of the percent of the Illinois river at the two cross-sections.

1995 (Diagram offered in evidence as complainant's exhibit 51.)

Q. Mr. Whipple, assuming that at a certain time Lake Michigan water contained an organism called cynedra pulchella sub prolongata variety, and that this plant is not contained at corresponding times in any of the branches tributary to the Illinois river, nor in the upper Mississippi water at Grafton, nor in the Missouri river water, and further assuming that this plant was found at a corresponding time in the water at the intake tower at St. Louis, what in your opinion does that show?

MR. TODD: I object to the question on the ground that the assumptions have not been established in the evidence, especially as to the Missouri river.

It would show that this synedra pulchella variety sub prolongata was not derived from the water of the Missouri river or from the water of the Mississippi river above Grafton, or

from the tributaries of the Illinois river, but that it
1996 came from Lake Michigan and was borne thither by the water from Lake Michigan.

1996 (Same question answered as to tabellaria.)

When the germs of typhoid fever are put into natural waters they will continue to live for several months, though in gradually decreasing numbers.

1997 From what I know about the life of the typhoid fever bacillus in the water, and from my knowledge of the conditions which exist between the Chicago Drainage canal and the intake of the waterworks of St. Louis, at the Chain of Rocks, it is my opinion that if typhoid fever germs exist in the sewage of Chicago, they will survive the passage down the Chicago Drainage canal and to the intake tower of the St. Louis waterworks at the Chain of Rocks under existing conditions. (The question to which this answer was given, assumes the water to reach St. Louis in ten and one-half days.)

1998 From personal observations to which I have testified (an inspection of the Chicago river, canal, and so forth) and assuming that the sewage and lake water passing through the Chicago river into the Drainage canal reaches the Mississippi at the Chain of Rocks, in ten and one-half days, it is my belief that typhoid fever germs coming from the sewers in Chicago, survive the passage through the Chicago Drainage canal, the Des Plaines river and the Illinois river to St. Louis. (Objected to by Mr. Hamlin and Mr. Todd.)

Under the conditions assumed (flood times) it is my judgment that a greater proportion of typhoid fever germs would reach the intake of the St. Louis waterworks from the Chicago Drainage canal when the time of transit was 8 days than when the time of transit was 10 1-2 days.

GENERAL HAMLIN: I move to exclude the answer on the same ground as previously stated.

1999 I believe from my general knowledge of typhoid fever epidemics that there are cases on record where such epidemics have occurred where the evidence shows that typhoid

fever germs considered to have caused the epidemic, remained in natural water for at least 10 01-2 days prior to the entrance of the water into the service pipes of the community where the epidemic prevailed. The cases on record of this character are those which occurred at Detroit, Michigan and at Lawrence, Massachusetts.

MR. TODD: I move to strike out the answer as not being competent evidence.

2000 From my knowledge of existing conditions of the Drainage canal and the several connecting water courses between that canal and the intake tower of the St. Louis waterworks, it is my opinion that there does not exist any efficient work of artificial construction which continually insures the prevention of typhoid fever germs, which may enter the Chicago Drainage canal, from reaching the intake. (Objected to by Mr. Hamlin and Mr. Todd.)

Q. Assuming that between Jan. 17, 1900, and Dec. 31, 1902, as compared with the period from 1885 to 1899 inclusive, there had been no increase on an average in the number of deaths from typhoid fever in those cities situated upon the Missouri river, upon the Mississippi river above Grafton and upon the Illinois river and its branches, exclusive of the Chicago Drainage canal, and further assuming that the typhoid fever death rate in the city of St. Louis had increased about 54 per cent on an average during this period, over the previous period mentioned, and further assuming that there was no substantial change in the manner of treatment of the water supply of St. Louis and assuming further that since January 17, 1900, a large part of the sewage of Chicago has been passed through the Drainage canal and thence into the Des Plaines river,

2001 the Illinois river, the Mississipi river, and into the intake, and assuming further that some of the water of the Mississippi river would contain a certain amount of Illinois river water at the intake of the waterworks at the Chain of Rocks,—state what, if anything, in your opinion the Chicago

sewage from the Drainage canal had to do with the increased typhoid death rate in St. Louis.

(Various objections by Mr. Hamlin and Mr. Todd.)

A. Under the assumption which you have mentioned, and if the conditions named are those which obtained, it is my judgment that the sewage of Chicago was the most probable cause of the increase of typhoid fever in the City of St. Louis which you mentioned.

1902 From my knowledge of existing conditions in the Drainage canal and the several connecting courses between that canal and the St. Louis waterworks, it is my opinion that no reliable and efficient natural agencies exist which can continuously insure the prevention of typhoid fever germs which may enter into the Drainage canal, from reaching the intake at St. Louis.

Q. Assuming that 106 barrels containing 40 gallons each of the culture of bacillus prodigiousus, etc., were emptied into the Drainage canal at La Monte, that at the time of this experiment this germ was absent in the waters under consideration in this case, and assuming that soon afterwards some colonies of bacillus prodigiousus on several occasions were found in samples of water taken from the intake tower at the Chain of Rocks, what, in your opinion, does this show? (Several objections by Mr. Todd and Mr. Johns.)

2003 It is my opinion that the origin of the bacilli found was the culture which was introduced into the Chicago Drainage canal. To judge from experiments which I have made and what I know generally on the subject, it is my judgment that the longevity of the typhoid fever and prodigiousus germs in natural waters is not greatly different. From my general sanitary knowledge, it is my judgment that the dejecta of typhoid fever patients would enter the sewage of Chicago—

GENERAL HAMLIN: That would, or does, did you say?

A. That do, I say, enter the sewers of Chicago, and that under the assumption mentioned, that the sewage of Chicago enters the Chicago Drainage canal, or has entered the Chicago

Drainage canal since its opening, since January 17, 1900, it is my judgment that the dejecta from the typhoid fever patients of Chicago enters via the sewers of Chicago, the Chicago Drainage canal, or the Chicago river, and the Chicago Drainage canal.

2006 GEORGE C. WHIPPLE: In my testimony yesterday I did not have at hand the average amount of chlorine in the water of the Illinois river above Grafton for the period between October 30, and November 29, 1901, which I used in calculating the percentage of Illinois river at various points in a cross-section of the Mississippi river at Alton. Upon consulting my notes I find that the average figure which I used was 20.3—this figure being an average of the results of daily chlorine determinations given upon one of the sheets in complainant's Exhibit No. 1 for identification. Neither did I have the figure for the average chlorine in the water of the Mississippi river above Grafton for the same period, and upon consulting my notes I find that the figure which I used was 3.9 parts per million of chlorines. This figure being an average of daily determination of chlorines given upon one of the sheets in complainant's Exhibit No. 1 for identification.

2007 I understand that those sheets are the results of examinations made by Teichmann and Keiser—under the direction of Mr. Teichmann.

2008 GENERAL HAMLIN: I move to exclude this statement or answer on the ground that it is a mere calculation testified to by this witness based upon tables that were not prepared by him and are not the subject of expert testimony.

Assuming that since January 17, 1900, a larger amount of the sewage of Chicago has entered the Des Plaines and Illinois rivers via the Drainage canal, than was previously the case, and assuming that water of the Illinois river containing such sewage, enters the Mississippi river and passes to the intake of the St. Louis waterworks, it is my judgment that since January 17, 1900, the water at the intake of the St. Louis water-

works has been relatively less safe for drinking purposes than prior to that time.

GENERAL HAMLIN: I move to exclude that answer for the reason the facts assumed in the question are not the facts as testified by complainant's witnesses and the records, so far.

It is my judgment that the most dangerous kinds of pollution of water supplies derived from rivers, lakes, ponds, or reservoirs, with reference to the safety of these waters for drinking purposes, are the dejecta and urine of human beings, such as are commonly found in the sewerage systems of cities and towns.

2009 CROSS-EXAMINATION by General Hamlin:

Made seven anaylses of the waters of the Mississippi river above Grafton, between the dates of October 16 and November 26, 1901. I received those samples at my laboratory in Brooklyn, New York. A number of years ago I made certain physical tests of the water of the Mississippi at Minneapolis. I ordinarily include under the general head of water analyses,

2010 such physical tests as that of the determination of color and turbidity. Such physical tests I made at Minneapolis some three or four years ago. I made no test for sediment ammonia, chlorines or organic matter, at that time excepting as the organic matter may be included in the color of the water.

Nor for nitrates or nitrites or total solids.

2011 I received seven samples from the Illinois river at Grafton between the dates of October 16 and November 26, 1901, from one or more collectors working under the direction of Dr. Ravold. The samples were received in glass bottles which had cork stoppers and these bottles were sealed when received. I do not make any chemical analysis of those waters.

Nor bacteriological examination.

2012 Those were all of the samples immediately above Grafton that I ever personally examined. And the ones that I have testified that I received above Grafton on the Mississippi, are the only ones that I have personally examined. I received some samples further up the Illinois river at Beardstown in the

month of November, 1901, sent to me by one or more collectors who worked under the direction of Dr. Ravold.

Q. Didn't you expect at that time to be a witness in this case?

A. I didn't consider the matter at that time.

2013 I don't remember just when I knew that I would be called as a witness.

I received five samples between October 16 and November 21, 1901, from sample collectors who worked under the direction of Dr. Ravold, and who collected the samples at Fort Bellefontaine. I did not make any chemical analysis of those samples, nor bacteriological examination. I regard myself and am regarded in my judgment, as an authority on the chemical analysis of waters and the bacteriological examination of waters. The next samples I received from the Missouri river were those which were collected by Prof. Van Ornum on April 12, 1903, the present year. I received three samples.

2014 They were all taken at a depth of ten feet. I did not make any chemical or bacteriological examination of these samples. I received the samples already mentioned (from the Mississippi river above the mouth of the Missouri) and in addition 8 samples collected in a cross-section known as section M and which were collected by Prof. Van Ornum on Apr. 10, 1903. Prof. Van Ornum is professor of civil engineering in the Washington University of this city. I did not make any chemical or bacteriological examination of these waters. That covers all the samples that I have ever received from that point. I received six samples of water from the Mississippi river at Alton, Illinois, which were collected between October 16 and November 21, 1901, and also 12 samples of the water of

2015 the Mississippi river above Alton, collected on November 12, 1901. I did not make any chemical analyses or bacteriological examination of those samples. I received seven samples of Mississippi river water at the Illinois shore, opposite the Chain of Rocks, which were collected between October 15 and November 29, 1901. Also 11 samples from Mississippi

river just above the Chain of Rocks, collected on November 10, 1901; also 7 samples from Mississippi river at intake, collected between October 15 and November 29, 1901. Also 24 samples from Mississippi river at cross-section which has been described as series C, just below the mouth of the Missouri river, which samples were collected by Prof. Van Ornum, on April 12, 1903. Also 33 samples from cross-section of the Mississippi river which has been described as series I, just above the intake, collected by Prof. Van Ornum on April 10, 1903. Those are all the samples. Cross-section I, I think, is about a quarter of a mile above the intake.

2016 Now these samples that I have mentioned, I did not make any chemical analysis or bacteriological examination of these samples. That is all the samples I received from the Mississippi or Missouri river, but I received other samples from the Illinois river. I received 6 samples from the Illinois river at a point 3 miles above Peoria, which were collected between October 16 and November 21, 1901, and which were sent to me by collectors who worked under the direction of Dr. Ravold. I did not make any chemical analysis or bacteriological examination of these samples. I received no other samples in any of the three rivers named, the Illinois, Missouri and Mississippi.

2017 I made no chemical analysis or bacteriological examination of the samples which I received from the tributaries of the Illinois river. I received 6 samples from the Chicago Drainage canal at the Bear Trap dam at Lockport, which were collected between October 17 and November 26, 1901. I did not make any chemical analysis or bacteriological examination of those samples. I received 4 samples which were marked Paulina street and which are included in this sheet marked Chicago Drainage canal, but I understood that these were collected from the Chicago river just before it enters the Chicago Drainage canal. These 4 samples were collected between November 8 and November 30, 1901. I received 5 samples from the Lake View crib between November 4 and November 22, 1901;

2018 3 from Carter Harrison crib between November 6 and November 15, 1901, and 2 from the 4 mile crib on November 20 and November 27, respectively, 1901. I did not make chemical analyses or bacteriological examinations of any of the samples mentioned. I made microscopical examinations of all of the samples mentioned, except those samples which were collected by Prof. Van Ornum. It does not include the 3 samples collected in the Missouri river on April 12, 1903. I didn't make chemical examinations of these samples or bacteriological examinations because I wasn't asked to do so. I could have made these examinations very easily. In my direct examination I stated that there were two microscopic organisms, vege-

2019 table plants, if you choose, synedra and tabellaria, which were especially characteristic of Lake Michigan water, but not of the waters of the Missouri or the Mississippi river above Grafton, or the tributaries of the Illinois river. I do not mean that these two do not exist in the waters of the Mississippi above Grafton. They might be found, as far as I know, in the Mississippi river above the mouth of the Illinois. I do not mean to say that they cannot be found or do not exist in the waters of the Missouri river. I do not mean to be understood as saying that they do not exist nor cannot be found, in the tributaries of the Illinois. These micro-organisms are usually found in the waters of lakes, ponds or reservoirs. I have no personal knowledge of how many lakes are situated on the Illinois river between Lockport and Grafton or whether or not there are any lakes or ponds that connect with the Mississippi river above Grafton.

Q. If there were lakes on the Illinois river between

2020 Lockport and Grafton that connect with the Illinois river, you would expect to find those micro-organisms, wouldn't you?

A. They might be found there.

Q. Well, wouldn't it be reasonable to suppose that they would be found there?

A. At times, yes, sir. And the same is true of the Missouri river and of the Mississippi river, under the same conditions. I never made any examinations of the waters of the Mississippi river below St. Louis. Never examined it at New Orleans to my recollection. I have seen the waterworks plant at Chain of Rocks, I have seen the pumping station at Baden; I have ridden along the conduit connecting the two. I have seen from the train the settling basins at Bissell's point.

2021 There are four settling basins at Bissell's point and six at the Chain of Rocks. That would make 10 all together counting each particular tank as a basin. Settling basins are used to get rid of the mud and to get rid of the suspended matter in the water also. It makes the water clearer and freer from suspended matter. It purifies the water to some extent by the removal of matter in suspension.

I consider the principal elements in the purification of water the removal of those substances which would render water impure.

Q. Has dilution anything to do with it?

A. If the water is diluted with another water which is purer than it is, it makes that first water purer. Sedimentation ordinarily makes the water purer. Dilution and sedimentation are regarded by scientists and sanitarians as two important elements in the purification of water.

2022 I wouldn't say they are regarded as the principal elements. In certain cases they are regarded as important elements. Settling basins are used in cities in cases where the original water contains large amounts of suspended matter which would settle out during the process of sedimentation. Natural water is any water found in nature. When I was asked some questions yesterday regarding sewage being discharged into natural water I meant natural water in that sense. That is the esnse in which I intended. That is the sense in which I have used the term during my entire examination by the complainant.

2023 I didn't prepare all the expert questions which were asked me yesterday. In some of them I assisted. I don't think I repeated any of them myself absolutely, or any one entire question. In my testimony yesterday in regard to chlorine, I used an average figure taken from the sheets of complainant's exhibit 1 for identification, which gave the chlorine in parts per million. I took the average, found in the Mississippi river above Grafton; in the Illinois river above Grafton and at five points in the cross-section of the Mississippi river at Alton and Hartford.

2024 I used that for the purpose of showing the mixture of the waters of the Illinois and the Mississippi. I didn't adopt the same plan of using the solids instead of the chlorines because there were no determinations of the total solids on those sheets at the five points in the two cross-sections at Alton and Hartford.

2025 Q. You stated yesterday, I think, to Mr. Jeffries, that the best test, that is the most reliable test, is the test made with solids?

A. I consider it to be such for the particular case which is being discussed, I wouldn't lay that down as a universal proposition.

2026 I believe that a mixing of the Illinois river with the waters of the Mississippi was evident at Alton.

The banks of the river from there to Grafton, from my recollection of the charts, I believe to be very nearly parallel with each other and very nearly in a straight line, barring slight irregularities. My recollection is that there are no im-

2027 portant curves. I think that the Illinois river water mixes with the water of the Mississippi by the time it reaches Alton, to some extent. That I understand to be about 15 miles away from where the rivers unite. I think it is about 6 miles from the mouth of the Missouri river to the St. Louis intake.

Q. In your examination you stated: "From my general knowledge of the subject of rivers and the effect of curves on

the currents of these rivers, it is my opinion that this curve which I have described (referring to a curve on the map or chart which you had in front of you) in the Mississippi river, between the mouth of the Missouri river and the intake of the St. Louis waterworks, would tend to allow or would increase or would be favorable to the mixture of the waters which come down the Mississippi river and the Missouri river." Now which one of those statements do you wish to adopt, "Would tend to allow, or would increase, or would be favorable?"

A. I don't think they mean the same, but I think they are all applicable. I wish to stand by all of them. I should say the mixture I speak of would take place most rapidly in that part of the curve where the central thread of the main channel crosses from the position near the left bank to a position near the right bank.

2028 That position or place is 2½ miles below the southern point of the mouth of the Missouri river.

2029 In the statements of the population made by me in my examination in chief, I did not state the total population of the watershed of the Illinois river.

2030 It is not true that all authors use the amount of urban population and the amount of rural population instead of the population of cities which have more than 4,000 inhabitants, as the population upon which they base their research. I think that where the pollution of a stream is involved, that the rural population is an element to be considered on the question of the discharge of sewage into that stream. I do not know what the rural population of the Illinois watershed is from my recollection. I find from the report of Jacob A. Harman, included in a report of the Illinois State Board of Health, on Sanitary Investigations of the Illinois river, 1901, on page 119, that in the year 1900, it was 893,723. That does not include Chicago but only the natural drainage of the Illinois river, and what he has called the rural population.

2031 I find in the same report and on the same page that the urban population for the same region for 1900 was 617,664.

Q. I will ask you if exclusive of the Chicago river and the I. & M. canal and the Drainage canal, if there are not about fifty creeks, rivers and tributaries to the Illinois river having their watershed drain into the Illinois river, making about 25,000 miles of creek, river and tributary draining portions of Indiana, Wisconsin, and a large part of Illinois, into the Illinois, which empties into the Mississippi river near Grafton?

A. I think that statement is approximately correct. But I find on page 120 of Mr. Harman's report that the sum of the areas of the watershed of the Illinois equals 27,814 square miles; and a memorandum from the 11th U. S. Census which states it to be 29,013 square miles and another from the Chief of the Weather Bureau from 1896 to 1897 which states it to be 29,150 square miles.

2032 I have no knowledge of the lineal number of miles of river or creeks draining into the Illinois river. All I know about the rural population upon the watershed of the Illinois river is what I get from this report of Mr. Harman's, he giving it at 893,723. The report of Mr. Harman I refer to does not undertake to give the urban and rural population of all the tributaries of the Illinois river, outside of the Chicago river, Illinois & Michigan canal and Drainage canal.

2035 It is impossible for me to say how much sewage is discharged into the Illinois river and its tributaries outside of the I. & M. canal, the Drainage canal and the Chicago

2036 river. I have no means of telling with any degree of certainty the amount of sewage discharged into the Illinois river exclusive of the Chicago river, the I. & M. canal and the Drainage district.

2038 In so far as the question of distance alone, is concerned, a typhoid fever bacillus would reach the intake of the St. Louis waterworks from St. Charles, Mo., or from Alton, Ill., more easily than a typhoid bacillus of equal vitality introduced



at a distance of 350 miles from the intake. But whether a typhoid bacillus discharged at St. Charles or at Alton would actually reach the intake of the St. Louis waterworks more easily than a typhoid bacillus of similar vitality, discharged at a distance of 350 miles from the intake, would depend among other things, upon the degree of mixing of the waters into which the bacilli were discharged, before they reached the intake, and to some extent, perhaps, upon the character of the water

2039 into which the bacillus which was introduced at a distance of 350 miles from the intake, was introduced. And it would depend still further upon the velocities of the streams into which the bacilli were discharged at the three points

2040 mentioned. If it depended on velocity, the one nearest the intake would reach the intake first provided the velocities of the streams were such that the one which was nearest the intake got the shortest time of transit. Alton is nearer the intake than a point 350 miles away, in so far as that flow is concerned, as I understand it.

Q. Do you want to be understood that a typhoid bacillus with equal vitality at Alton and starting on his journey to the intake, with one of equal vitality 350 miles away, that one would be as liable to reach the intake as the other, and still maintain their vitality?

2041 If by vitality you mean the ability to resist external conditions, that would depend upon the relative character of the water into which the bacillus was introduced at Alton, and the water into which the bacillus was introduced at a distance of 350 miles, and the time required for the bacillus to travel from Alton to the intake, as compared with the time required for the bacillus to travel from a point 350 miles away to the intake of the waterworks.

From memorandum that I have read, according to the 11th Census of the U. S., the drainage area of the Missouri river was about 527,000 square miles and according to report of Chief of Weather Bureau for 1896 and 1897, was about 527,150 square miles; the drainage area of the Mississippi river above Grafton

according to 11th U. S. Census was about 143,512 square miles and according to report of Chief of Weather Bureau it was 126,750 square miles, while the drainage area of the Illinois river I have already given. Making a total for the three watersheds of the three rivers mentioned, and excluding the I. & M. canal and Drainage canal, of 699,525 square miles according to the U. S. Census and 693,050 according to the Chief of Weather Bureau.

2042 If, by urban population we include the population only of those towns and villages and cities which contain more than 4,000 inhabitants, I find on page 27 of the report on the water supply of St. Louis by the Commission of Hydraulic Engineers, dated 1902, that the aggregate urban population on the three watersheds mentioned in the last question was, according to the U. S. Census of 1900, 2,694,738. I do not know what the rural population is.

Q. I will get you to state if it is not a fact that in this area of these three rivers, that you have mentioned, that is within these drainage basins, exclusive of the Chicago river, the I. & M. canal and the Drainage district, if the population according to the United States Census was over 12,000,000?

A. I don't know as I haven't made any estimate of such a population.

2045 If we assume there are 12,000,000 inhabitants living upon the watershed of the Missouri river and the Mississippi river above Grafton, and the Illinois above Grafton, exclusive of the population living within the Chicago Sanitary District, and if we assume that there are living within the Chicago Sanitary District 1,639,456 inhabitants, and if we assume that the amount of sewage from each individual is the same as the amount of sewage from every other individual upon the three watershds mentioned and within the sanitary district, and if we assume further that all the sewage from all these individuals mentioned as living upon the three watersheds, and within the Sanitary District empties into the streams mentioned, the

amount of sewage contributed by the inhabitants of the sanitary district of Chicago would be about 13.6 per cent of the amount of sewage contributed by the 12,000,000 population dwelling upon the three watersheds mentioned, exclusive of the Sanitary District.

2047 According to the authenticated cases of the contamination of water that has produced typhoid fever, to the best of my recollection and in the absence of my notes, it is my opinion that the distance from the point or place where typhoid fever was contracted from the point of contamination, has been *as great at times as 50 or 60 miles.*

I should say that the majority of the well recognized epidemics caused by water borne typhoid fever bacillus were due to infection less than 30 miles distant.

2051 The best way to determine the presence of sewage in water is to actually find out whether or not sewage enters the water.

Q. In the absence of that information can water be taken from a river and by any process known to science, can it be determined whether that water is sewage polluted or not?

A. Some water can be and some water cannot be. If water is much polluted with sewage that fact can be ascertained by scientific methods; if it is but very slightly polluted with sewage, it cannot always be determined by scientific methods. I have not a definite idea as to what degree of pollution I denominate much polluted.

2055 Q. Then, in order to ascertain the presence of sewage in water of the character that we have been talking about, with these elements eliminated, is it necessary to make a chemical analysis of the sewage before it enters that water, in order to ascertain the proportion of the sewage to the water into which it enters, in order to ascertain its presence?

A. In order to ascertain the proportion of the particular sewage mentioned, it would be necessary to make some sort of an analysis. In the absence of any analysis having been made of the sewage before it enters the water it might be possible to

ascertain its presence in the water into which it empties but not its exact proportion.

2056 Q. Do you know the character of the waters of Lake Michigan when freed from any sewage pollution from Chicago?

A. Only from analyses of such portions of Lake Michigan as are used for the water supply of Chicago. I couldn't state definitely whether that is free from sewage contamination or not. I am not able to state from my knowledge of the

2057 sewage of Chicago before it commingles with the waters of Lake Michigan at what proportion of water to sewage I would be able to ascertain the presence of sewage in that water.

Q. Your experience as a scientist has not enabled you to make that kind of a determination, has it?

A. It has not enabled me to determine that point exactly. I do not know of any scientist of established standing or admitted standing that has been really able to solve it.

Q. Then the line between much polluted water and slightly polluted water has never been scientifically defined as to the ratio of sewage to water, or dilution, has it?

A. It is my opinion that it has not been truly defined, and that it cannot be truly defined.

If a scientist did not know that the sewage entered the water, and if he didn't know the character of the water before the sewage entered it, the question of whether he could determine the probable presence of sewage in that water, would depend in part, upon the original character of the water and the character of the results shown by his analysis.

Q. If he didn't know the character of the water into which the sewage entered, or the character of the sewage that entered the water, in fact didn't know that any sewage entered the water at all, what would have to be the results of the analyses in order to demonstrate the presence of sewage in the water?

A. I should be unable to state in definite terms.

Q. Do you know?

A. Not in definite terms, no, sir.

2058 If I didn't know the character of the water originally or the character of the sewage; if I obtained from my analysis results which approached those in character which would ordinarily be obtained by the analysis of sewage, I should be able to form a fairly reliable opinion as to the presence of sewage in the water. I should compare the qualities which have been already enumerated, namely, the amount of organic matter as shown by albuminoid ammonia, the character of the organic matter as indicated by the free ammonia, the nitrites and nitrates; the amount of total solid matter, the matter in suspension, the chlorine, the hardness, the prevalence of certain particular species of bacteria, such for example, as the bacillus coli; the number of bacteria, the color, the presence of certain microscopic organisms, etc.

2059 There is no one element to which I should attach special prominence. Suppose some of these elements were absent, I might be able to conclude the presence of sewage pollution, but my judgment would be to that extent, or to the existence of the pollution, less reliable. Albuminoid ammonia in water serves as a measure of the amount of undecomposed organic matter present, but taken by itself, it cannot be used to determine the amount of sewage pollution present.

2060 There is no such substance as albuminoid ammonia. It is simply a form of expression for describing the amount of organic matter present. It is a form of expression for the substance and is not the name of the substance itself.

Q. Chemistry is an exact science, isn't it?

A. Fairly so.

2061 If the water is said to contain free ammonia, we meant that the water contains ammonium compounds which are such as upon boiling the water the ammonia will be driven off in such a way that its amount can be determined. Nitrites

are both a name for a substance and a substance. Nitrates are also a substance which may exist in water.

2062 You can get the nitrogen of free ammonia as the term is used in water analysis, from the nitrites and nitrates. The substance for which the term albuminoid ammonia stands, may be derived either from animal or vegetable matter. In fact, it may be animal or vegetable matter. When I find the presence of albuminoid ammonia in water the science of chemistry does not enable me to ascertain whether that albuminoid ammonia comes from animal or vegetable origin.

2063 From any methods of chemical analysis with which I am familiar, it is impossible to tell whether the substance represented by the term albuminoid ammonia, is derived from animal or vegetable matter. The origin of the free ammonia which may be present, whether from vegetable or animal matter, cannot be definitely determined, although if the amount of free ammonia is high compared to the amount of albuminoid ammonia found, there is, to some extent, more reason to expect that it comes from animal matter, using the terms free ammonia as standing for the substances. I should say that that fact rises to the dignity of a scientific demonstration.

2064 Now that which is true of free ammonia is true of nitrites and nitrates, is it not, as to the origin, whether animal or vegetable?

A. Not in the same sense, because nitrates may come from substances of mineral character. It is a fact that the substances which you describe as free ammonia, that the nitrogen of that substance may become changed to nitrites, and afterwards to nitrates under the influence of certain bacteria.

2065 If you found nitrates in the water analysis, these nitrates may come not only from animal and vegetable, but also from mineral origin. When they come from mineral origin it does not come from sewage unless the sewage contains minerals from which they came. Sewage contains mineral matter besides chlorine. If these nitrates come from mineral, I couldn't say definitely that they came from mineral sewage or

without knowing whether any of the sewage entered the water, or whether the water in any way came into contact with minerals which would give up nitrates. Speaking popularly, minerals do not come from vegetables, but in so far as nitrates represent mineral matter, these might be derived under the action of bacteria, from vegetable matter.

2066 If nitrates are found in the chemical analyses of water, their presence there does not indicate from what source they have their origin—whether vegetable, animal or mineral, simply because they are found there. The hardness of water is an attribute which is derived chiefly from mineral origin. It might be derived from sewage pollution to some extent when the sewage is from the fecal and urinal discharge of man.

Q. To what extent would you consider it?

A. I could not express that in definite terms, but I might say that would be a smaller fact to be considered than most of the other elements which I have mentioned. Of itself it would not decide sewage pollution.

2068 Q. Now, from the table and analyses that you have before you, (Complainant's exhibit 1 for identification) are you able to tell whether that sample of water was sewage polluted or not, or whether those elements are derived from animal or vegetable origin?

A. I am not able to tell either of those things from these figures as I find them right here, considering nothing else, than these figures.

2069 What other element would you consider in connection with those analyses in order to determine whether the chlorine, albuminoid ammonia, free ammonia, nitrites and nitrates were derived from animal or vegetable origin, as indicated in those tables marked Complainant's Exhibit 1 for identification?

A. I should want to have more information—more practical information in regard to the source of this sample and the place from which it was derived. That table indicates that sample was taken at Fort Bellefontaine, in the Missouri river.

That gives the locality of the sample, as to place and the river from whence it was taken. I should like also to know the character of the watershed from which this sample of water was derived, with reference to the existing pollutions. I think the analysis is of such a character that it would be difficult to tell from the analysis itself, whether or not this water were sewage polluted without knowing the character of the watershed. Assuming that the sewage of Kansas City, Kansas, and the sewage of Kansas City, Missouri, and the sewage from slaughter houses and cattle sheds located at those two places, emptied into the Missouri river about 400 miles above this point, those facts would indicate that this water might perhaps be sewage polluted, except in so far as the effects of the pollution may not have been interferred with by processes of sedimentation, etc., between the point of pollution and the

2070 point where this sample was collected. I should have to balance a number of different conditions in order to arrive at such a result.

2071 Q. Do you consider the water of the Missouri river above Kansas City a sewage polluted water?

A. In so far as the sewage of the cities dwelling upon the watershed of the river above that point enters the river, I should consider it as a sewage polluted river. Whether suitable for drinking purposes I am unable to state from the facts which I have at hand.

2072 I stated that whether the sewage of Kansas City reached Fort Bellefontaine in quantities sufficient to be detected, or have any effect upon the water when used for drinking purposes, depended upon dilution, sedimentation, the action of bacteria—I would say the possible action of bacteria and microscopic organisms or other such natural agencies and I understand you are barring out any artificial actions which might be introduced. The amount of dilution necessary to meet the requirements of my answer would depend upon the character and the amount of the sewage and also perhaps upon the relative effect of some of the other agencies mentioned, including,

for example, the time of transit of the water from the one place to the other. I don't know the exact amounts of dilution because I don't know the volume of the sewage and I don't know the volume of the stream at that point.

2075 The presence of the bacilli coli communis I could not state definite that it indicates sewage origin. It is believed by many scientists today that this organism may be found in waters where pollution may be remote. I hold that if this organism is constantly present, or is very often present in a water, and if this organism is present in such numbers that we can readily determine its presence by analyzing one cubic centimeter or less of the water, it is probable that this is an indication of contamination by fecal matter. I do not believe that the test is an absolute test, but I consider it is a valuable one to be interpreted in connection with the rest of the analysis.

2076 The bacilli coli communis is found most commonly in the intestines of man and certain animals, for example, the cow, horse, pig and I think birds and speaking generally, in warm blooded animals.

It has been my experience that the intestines of fish do not ordinarily contain bacillus, and that if this bacillus is found there, it is a case where the bacillus has been derived from the water, and I base my judgment upon considerable personal work which I have done in that direction. I would disregard its presence in the intestines of fish in the Missouri river so far as any interpretation were made from the presence of the coli communis in the water.

2078 Q. What organisms—what micro organisms found in water demonstrate sewage pollution from the fecal discharge of man?

A. I don't know of any that absolutely demonstrate its presence, but there are certain microscopic organisms or microorganisms which are so often associated with sewage that in a very general way they do serve as an index of the presence of sewage, but I wish to be understood as saying that they indicate

it only in a general way. I could not assert that a stream was sewage polluted because these organisms were found in the water, barring all other considerations. There are none of the elements which you have mentioned taken singly, that would demonstrate their origin to come from the fecal discharge or the urine discharge of man, if found in waters. And even when taken collectively, they are not able to demonstrate their origin as coming from the urine or feces of man, but taken collectively and making comparisons with what we know of their character and amount of sewage, we are sometimes able to judge as to whether or not a water may be polluted with sewage which presumably contains the dejecta and urine of man. I wouldn't call that a straight scientific demonstration, but I would consider it what you may call a reasonably correct judgment. That judgment is liable to be mistaken like all human judgments.

2081 I don't know definitely how long the bacillus of typhoid will live in sewage contaminated water. I don't know of any scientist who actually knows. I know the bacillus of typhoid will live in sewage polluted water, but scientists have made laboratory experiments to determine that fact and they have arrived at certain conclusions. I do not consider conditions in the laboratory where experiments have been made similar to conditions that exist in a running stream, sewage polluted.

2082 I know of people who have claimed to have discovered the germ of typhoid in running waters, but I am unable to state whether they actually did discover that germ in running waters or not.

2083 I don't see how it is possible in the present state of bacteriology for reliable experiments to be made as to the rate typhoid bacillus dies out in running waters.

2085 I believe that the best scientific information which we have leaves us to suppose that after leaving the human system, typhoid bacilli do not ordinarily multiply in the water.

Q. Would the presence of lakes in the river act as settling

basins for the purification of the sewage discharged from the Drainage canal at Lockport?

A. If such lakes were present on the Illinois river, and if in such lakes the water therein should become more quiescent than in that of other portions of the stream, the suspended matter of the sewage—the suspended portions of the sewage might tend to settle more rapidly than in the swifter portions of the stream. Purification of the water which contained the sewage would depend in part upon what happened to the suspended matter after it had settled, and whether or not the suspended matter was afterwards carried into the stream again, to Grafton.

From what I have learned from reading various reports which describe the conditions of the Illinois river between Lockport and Grafton, it is my opinion that at times such sedimentation may take place. That is at times when the

2086 velocity of the water in the stream was low. Flood conditions would add to the dilution. They would increase the dilution of the sewage.

2087 There are four dams in the Illinois river.

They are there for the purpose of assisting navigation by raising the water and backing it up stream. Now when the water in the Illinois river is at normal and is backed up by these dams, would not the backing of the water up above the dams act as settling basins?

A. If in this water above the dams the velocities were reduced to such a degree that sedimentation of suspended matter could take place.

2088 Q. What is your individual judgment upon the subject as to the speed of a current that would be necessary in order to permit sedimentation?

A. My judgment is that if the velocity is reduced say from a quarter to one-third, or perhaps to a half a foot per second, sedimentation of suspended matter of a certain character might occur. If the suspended matter were coarser, it

would settle with greater velocities. I can imagine suspended matter so fine that it would not settle even at those velocities.

Q. Suppose that the current was a mile in two hours, would sedimentation take place?

A. I think it would, sedimentation of substances of a certain character.

2089 Those four dams in the Illinois river, I think they would allow sedimentation to take place under more favorable conditions than if they were not there to just the extent to which they reduced the velocity of the stream. Of course we understand that the laws governing sedimentation of suspended matter would apply to the Illinois river the same as they would apply to other streams, and I know from reports that sedimentation actually is said to take place in the Illinois river at certain places. I think that a velocity of one mile in two hours would allow sedimentation of a certain size or kind of suspended matter to take place. Under the conditions which exist, it is my judgment that the proportions of the sewage, of all parts of the sewage of the city of Chicago, would not be eliminated by the time that it reached Peoria. I am unable to state definitely what part would be.

2090 I said parts of the sewage, and when I said parts I did not mean a half, or a quarter or an eighth or sixteenth. I mean parts of the sewage, understanding that sewage is not a single substance, but is composed of various ingredients. If we take chlorine, for instance, which is a constituent of sewage, that chlorine would not be affected by sedimentation, for instance, but practically by dilution, and to that extent the sewage of Chicago would not be eliminated by the time it reached Peoria, but simply reduced in amount by the dilution it might receive. From what I know of the existing conditions on the watershed of the Missouri river and from the fact that there are certain salt deposits, and from analysis which I have seen showing the indication of such salt deposits, of the effect of such salt deposits on the water of the Kaw river, it is my opinion that the chlorine in the Missouri river, in its low

reaches, cannot be used as an index of pollution, although part of it may be derived from sewage pollution, because the effect of the chlorine from the salt deposits, would simply mask any chlorine from sewage pollution, and in that particular case the chlorine could not be used to determine whether or not the water was sewage polluted.

2091 Q. Is it your opinion, and I believe you stated that the increase in typhoid in the city of St. Louis, is due to the sewage from the Drainage canal, from 1900, 1901 and 1902?

A. I think that I stated that under certain conditions which were assumed, the most probable cause of the increased typhoid in the city of St. Louis during that period was due to the sewage of Chicago, meaning by that that was the easiest explanation of the increase under the conditions which were assumed.

Q. Does an easy explanation always explain, Mr. Whipple?

A. It doesn't always explain.

2095 You cannot state as an established fact that the opening of the canal at Lockport is the cause of the increase in typhoid in St. Louis, can you?

A. I cannot state it as an established fact absolutely, and conclusively proved.

2096 I don't know that the sewage of Peoria purifies itself in 25 or 50 miles. If you mean by purification, the fact that the water into which the sewage of Peoria is discharged because free from all the constituents of that sewage, if you put the time within 25 or 50 miles, or if you mean by purification the fact that the water into which the sewage of Peoria is discharged, becomes free from all the constituents of that sewage, I should say that it did not.

Q. Would it purify itself by the time it got to the St. Louis intake?

A. If you mean by purification of the sewage the fact that all of the elements of the sewage were absolutely removed from the water I should say that it did not, but in connection

with both of these answers, I wish it to be understood that the factors of dilution, etc., must be taken into consideration. Chlorine in water is not injurious to health unless you get an excessive quantity of it and it would probably be impossible to get enough to injure one as I understand your question. In order to make water dangerous to the public health, it must contain something which would affect the human system, and that something would ordinarily be a pathogenic germ, rather than any form of poison, or anything of that sort. If

2097 you wanted to know the character of the microscopic organisms in the water for the entire year and the changes which might take place in the number of microscopic organisms present at different seasons, the samples should be taken at different seasons of the year, and the more frequently these samples were taken the better would be our knowledge in regard to the general character of the water with respect to microscopic organisms. Take one set of samples in a cross-section of the Illinois river and examine them microscopically, and we would learn the condition of the water at the point where the samples were collected at that time.

2098 That determination might not apply to the conditions of the river a month previous or a month subsequent. One set of samples taken at a selected time would give reliable information as to the character of the water of that stream at that time at the point where the sample was taken.

Q. And at no other time, or at no other point?

A. No, sir, so far as those samples alone were concerned, and in the absence of any one from which we know that those waters remained constant in character through a period of time.

2100 In making up an opinion as to the conditions of these rivers, I have assumed that the results which I have seen as tabulated or published, were correct.

2101 I do not consider that there is a well defined standard regarding what I may term the safety of water with respect to its use for drinking purposes, excepting that of the

absence of substances which might render the water unsafe. It is my opinion that it is practically unknown subject as to whether or not the presence of microscopic organisms would render a water which once unsafe, safer for use than if they were not present. So that the presence of a greater or less quantity of any kind of micro-organisms such as I have named, is not indicative that the water is undergoing a process of purification.

2102 Any one of these groups, (diatomaceae, chlorophyceae and protozoa) might encounter conditions which might exterminate them so far as their life were concerned, but I have already testified that the cell walls of the diatomes are practically indestructible in water. Diatomes are found in all surface waters, to a more or less extent.

2103 The synedra pulchella variety sub prolongata is more commonly found in ponds—in the waters of ponds and lakes than in the waters of streams, except in so far as those streams might be fed by lakes which contain them. I mean the natural habitat of the organism is in ponds and lakes. That is also true of some species of tabellaria. If the variety of synedra which I have mentioned, and the tabellaria could be required to pass through twenty miles of what has been called pure sewage, I think it might survive the journey.

2104 Assuming that the Illinois river has upon both banks from Joliet to Grafton, or from La Salle to Grafton, large numbers of ponds and lakes, many of which are fed by springs, over-flowing in time of high water, and acting as feeders to the Illinois river in time of low water, having their low water outlet into the Illinois river, the synedra and the tabellaria of which I speak exist there.

2105 If we have a certain volume of water contributed by the tributaries of the Illinois river, and the assumed lakes which are assumed to contain a certain number of these organisms, and if we have a greater volume of water from the Chicago Drainage canal which contains per cubic centimeter an equal

number of these organisms; then if we assume a thorough mixing of the waters, it would be my judgment that the organisms found in the resulting water would be more likely to come from Lake Michigan than from the other sources named—it would be my judgment that these organisms would come from both sources, but that more of them would come from the water which was greatest in volume, provided that the two waters contained an equal number per cubic centimeter. All other consider-
2106 ations being equal. I don't think the fact that the supposed organisms traveled through 22 or 24 miles of sewage, of any consequence, for the reason that in the examinations that I have made I have not attempted to differentiate between a live synedra and a synedra not capable of de-
2109 veloping. I do not know that one thousand million bacillus prodigiosus could be concentrated in one cubic centimeter and exist for two days alive. A bacillus may be carried by water from one point to another provided nothing happens to it on the passage. I suppose it might be taken from the river by pump and through along the decks of a steamer traveling up the river, in the process of washing decks, and go out into the river again, five or ten miles above where it was taken from. If conditions were favorable, a bacillus might be taken in a portion of water and put in a boat and carried up stream and then put down in the water again.

2110 I think that the bacillus—speaking in general—might, under certain conditions, become attached to a duck, for example, the duck might travel up stream and the bacilius might get away from the duck and go into the water. I think it might be taken up by a duck or through a pump and be used for the purpose of washing the decks of a boat and returned to the water again alive, three or four miles or ten miles from where it was taken out. So far my knowledge goes, that principle would apply as well to prodigiosus as to any other bacillus. The fact that the bacillus prodigiosus—one colony of them —was found three miles up-stream from the place at which it

was put into the river, would simply show that the water at that point, at that time contained this bacillus.

2111 It is my opinion that if the bacillus were taken out from the place where it was put in and carried up by boat three miles and put into the water—it would be there. I think it would bear the transportation probably, under the circumstances which you have mentioned.

Q. Suppose bacilli, naturally inhabitants of running waters which are turbid to some extent, should be removed from their natural place of abode, developed by special culture, put in bottles of sterilized water, and hung out in the sun, would that be a fair means of determining how long they live in their natural waters?

A. I don't think it would enable us to tell how long they would live in their natural waters, no, sir.

2112 An experiment of that kind does not enable us to give a definite opinion as to the life of any particular bacillus in its natural situation.

2113 Q. Taking into consideration all that you know of the physical conditions surrounding the Drainage canal, Illinois river, the Mississippi river and the intake, and the character of the prodigiosus bacillus, and assuming that some bacillus were put in near the mouth of the Illinois river in August, 1900, and in November, 1901, 107 barrels of them were put in near Lockport, and that they were afterwards found at the intake and in taps of the city waterworks here, could you tell, with any kind of certainty, to which dose of the bacillus put in those waters, those found were to be attributed?

A. It is my judgment that if those came from either the one dose or the other, that they came from the second dose rather than the first.

2115 If you consider the question of percentage mixture, I would say that the percentage of mixture of the two waters would not be the same at all times, of Mississippi and Missouri water.

2116 As a rule, if we consider a certain point below the point of mixture, the percentage of the waters would not be the same at all times, on account of natural variations in the flows of the two streams, and questions concerning their currents, etc., so that when it is determined that upon a certain day the percentage of the Mississippi water and the percentage of Missouri river water bear certain relative proportions to each other, that determination would not necessarily apply to any time. It would simply apply to that one time. When I testified here to percentages of volume of water of the Missouri river and the Mississippi river at the intake, based upon total solids and also upon the chlorine as to the Illinois and the Mississippi, I meant to say that the percentage of water carried a certain percentage of the solids in solution and represent relatively the volumes of the water as far as the solids represented the samples.

2117 I think if the determinations for the chlorine represent fairly the waters from which the samples are taken, that the calculations will give us the limits of accuracy governed by the sample and the determinations of the percentages of the two waters.

2119 (See pages 2118 and 2119 for method employed in determining percentage of Illinois and Mississippi river at various points.)

2120 CROSS-EXAMINATION by Judge Springer:

2121 The larger the number of samples and the more complete the examination made, the better judgment we could make of the sanitary condition of the water or the sample analyzed. Microscopic examinations of water cannot be depended upon to determine the pathogenic qualities of drinking water. So far as I know the common microscopic organisms found in water are not the cause of disease. Their presence does not definitely indicate pollution but as I have already testified, there are certain forms of microscopic organisms which are so commonly found in waters known to be polluted that to some extent their presence in water is indicative of pollution—to a

ical examination does not definitely determine the nature of the organic matter in the water. Some microscopic organisms are very susceptible to changed conditions of temperature and light.

2122 In order to obtain the most accurate result, the bacteriological examination of a sample of water should be begun immediately after the time when the sample is collected, but the character of the water would, to a considerable extent, influence this fact. Water which came from the Illinois river during the months of October and November should be examined immediately after the sample was collected or within a few hours of the time of its collection.

2124 As to the samples I examined microscopically and which were examined three or four days after being taken, I would say the results would have been the same if I had examined them immediately upon being taken from the water, so far as diatomes are concerned, but perhaps not so far as some of the more delicate forms are concerned.

2125 I stated in my examination that there were two organisms which I called synedra pulchella variety sub prolongata, and tabellaria which were especially characteristic of Lake Michigan waters, but I think I stated that only with regard to the synedra pulchella variety sub prolongata, that that organism was not found anywhere else than in the water of Lake Michigan, or the waters with which Lake Michigan might have been afterwards mixed. The microscopic organisms which I found in Lake Michigan are found in all parts of the world and in great variety of climatic conditions, speaking generally. These organisms have received a great deal of attention.

Q. Are the laws governing their distribution in determining the places at which they may be found, understood at this time by scientists?

A. They are certainly not fully understood. I think we are beginning to understand something concerning these laws.

Q. May not a certain genus of the varieties to which you have referred, grow vigorously in one pond or place, and be absent from a neighboring pond where the conditions are equally as favorable for its existence?

A. Yes, so far as we know those conditions, I can recall such cases.

Q. Does it not often happen that a certain genus of the species to which you have referred may suddenly appear in a pond, lake or water in which it has never been before seen?

A. They certainly do suddenly appear in waters where apparently they have not before been seen, but just how far back observation has extended in regard to the previous history of that water, or just how far observations of a scientific character have been made concerning that water, would have to be taken into account in comparing their presence to-day with their presence on former days.

2126 An examination of a sample of the water in the Missouri river, or in the Mississippi river above Grafton taken today might show the presence of the two genera which I failed to find in the samples found in Lake Michigan.

2128 The samples of water that I examined microscopically were taken in October and November. If additional samples of water had been taken during that year in other months, at Fort Bellefontaine and in the Mississippi river above Grafton, it might be that I would have found the two genera of micro-organisms which I failed to find in the samples submitted to me from those points.

In the typhoid epidemic of Lawrence, which I mentioned, it was supposed that the bacilli travelled somewhere near 21 miles.

2129 The other case, which was that of Detroit, the distance travelled was from 50 to 60 miles. I think I have heard of greater distances, but I am unable to recall at the present moment. I mentioned the distance of 50 or 60 miles the other day, because I felt quite sure it had been carried at least that. The distance travelled is only an important factor in so far as

it affects the time required for the bacilli to travel through water. I don't think it is any question of linear distance so much as it is time transit. There are a great many other elements to be considered, for example, the so-called vitality of the organisms; the rate at which they die out in water, the rapidity of the current in which they flow; with reference to possible sedimentation; the possible phenomena that they might settle to the bottom of the stream and again be taken from the bottom of the stream and carried down; the question of the tem-
2130 perature of the water might influence their vitality and the character of the water might, to some extent. I think it is the concensus of the opinion of scientists that such a pathogenic germ as typhoid fever for example does not develop in water, but on the contrary dies out.

2131 Their presence is best accounted for by considering the probable presence of the dejecta and urine of human beings which contain such bacilli so that when any of these pathogenic germs are destroyed in transitu they reduce of course the possibility of transmission of disease in proportion to the number destroyed in transitu. Scientists or authors have not ascertained by any experiments today the probable duration of pathogenic germs such as typhoid fever, in running water except by means of laboratory experiments which naturally cannot be made under the same conditions as actually exist in running waters. It is my opinion, speaking generally, that the laboratory experiment would be less favorable to their longevity than the natural conditions. (Witness is shown "Microorganisms in Water," by Percy and G. C. Frankland, showing experiments made as to the longevity of typhoid bacillus.)

2133 From those figures I should question whether the results that he actually obtained would stand the test of the bacteriology of the present day.

2134 I considered the question of sedimentation in those expansions of the Illinois river to which references have been made and it is my opinion that under certain conditions, sedi-

mentation of bacteria might certainly occur in those places.

2136 The greater the amount of dilution of a polluted water, the less danger there would be from drinking this water, so far as dilution alone is concerned.

2137 It is quite conceivable that the conditions in the Illinois river between the Chicago Drainage canal and Peoria (taking into consideration the Narrows) are such that the total numbers of bacteria in the Illinois river at that point, might be as low or even lower than the numbers of bacteria in the waters of Lake Michigan before it received the sewage of Chicago, but I would add to that, that when we speak of a bacteriological condition, we must consider not only the number present but also the character of those bacteria. The probability is that pathogenic germs would decrease, but whether or not they would decrease exactly in proportion to the water bacteria, is a thing which I cannot state.

2138 It is my general impression from experiments that have been made, that at most temperatures water bacteria would live longer in water than the typhoid bacilli. If we neglect all other conditions, such as sedimentation, etc., etc., and consider only the fact that typhoid bacilli do not multiply in water, while water bacteria do multiply under the conditions assumed, why then it is probable that the typhoid bacilli would not linger in water as long as the bacilli which multiplied there, but as a natural practice it would not do to neglect all such other considerations in studying a problem of that character.

2139 Q. This work by Percy and G. C. Frankland, on pages 100, 101 and 102, refers to experiments made by one of the authors, by bacteriological examination of the waters of the River Dee in Scotland, the results shown here are that near the mouth of the river the waters exhibited about the same number of micro-organisms as it did 40 miles up the river and that there were as many as four different sources of pollution entering the river and that after each one, the river reached its normal condi-

tion and came out at the end comparatively bacterially pure. In view of these facts, is it not highly probable that the waters of the Illinois river, in passing from Joliet to the Narrows, above Peoria—a distance of over 100 miles—were rendered comparatively bacterially pure, by reason of the sedimentation, oxidation and other causes tending to the purification of rivers?

(Objection by Mr. Jeffries.)

A. It is my opinion that the conditions which exist in the River Dee have not been described with sufficient completeness as to the amount of dilution, course of the stream, sedimentation, etc., to enable a fair comparison between the River Dee and the Illinois river.

2141 Assuming that there was a typhoid epidemic in 1890 in cities on the Missouri and Mississippi and that the sewage of the respective cities was emptied into the Missouri and Mississippi rivers, speaking very generally, the danger of contracting typhoid fever by drinking the water of those streams would decrease down the stream.

2142 Q. Then the danger of contamination of the lower river would be lessened in proportion as the pathogenic germs were eliminated by the sedimentation and other causes to which you have referred?

A. The danger from drinking the water in the stream further down the river is certainly lessened in proportion as typhoid fever germs are actually eliminated from the water.

(Question propounded in which the number of deaths from typhoid and population of various cities which drain their sewage in the Mississippi and Missouri rivers, is given, the number of deaths from typhoid being in each instance from 4.5 per 10,000 to 21.7, ending with New Orleans with 1.9 per 10,000.)

Q. How do you account for the fact that the death rate of New Orleans, which was 1.9 per 10,000 persons was less than it was in any of the up-stream cities to which I have referred?

A. The problem is too big a one to be solved without knowing many more conditions than anything that I have at hand at this moment, aside from these figures.

2144 I have no doubt that starting with Denver and the Missouri river and St. Paul on the Mississippi river, and continuing down the two streams, both before and after their junction, that in so far as the bacilli—typhoid fever bacilli in the sewage of those cities are concerned, there was an increasing dilution; there may have been sedimentation; there was no doubt a dying out of the typhoid fever bacilli. On the other hand, some of the bacilli which settled may have been again carried into suspension and borne a distance, possibly to be again settled; possibly to be again carried on, and I should judge from these figures, that the water which was being used by the people of New Orleans, for example, was less dangerous from the standpoint of typhoid fever, than the water which was being used by the city of Memphis, for example, assuming that there were no local conditions or no other conditions to account for the difference in the typhoid fever rate. In short, the death rate from the typhoid fever in the two cities for a certain period offers a fair index for the comparison of the danger of the two water supplies for the period, irrespective of other causes which might account for some of the cases aside from the water.

2146 I do not think it is universally recognized as a fact that the greatest pollution in streams of water is at times when the flood is greatest or the flow of water is the greatest. At times of flood or spring rains, there might be a greater amount of polluting matter washed into the streams but, on the other hand at such times the volume of water is usually large and dilution greater, so that the result might not be different from what would occur under normal conditions by the constant pollution of the stream by a sewer, for instance. I do not believe there is any practical method by which pathogenic germs can be determined in water, either chemically or bacteriologically.

2148 I believe it to be a fair statement to say that in ordinary natural running waters, there is no practical method by which the presence of the typhoid fever bacillus can be deter-

mined. I do not think it is absolutely impossible to do so, but there is no practical every-day method for doing it.

The germ might be there and you might fail to find it and it might not be there when you failed to find it.

RE-DIRECT EXAMINATION by General Crow:

I certainly believe that the liquid leaving the Chicago Drainage canal at Lockport is polluted.

2149 If we consider the liquid which leaves the Chicago Drainage canal at Lockport to be polluted sewage, and to be flowing at the rate of 300,000 cubic feet per minute, and if to that is added 40,000 cubic feet per minute of diluting water, the sum of these two amounts would be 340,000 cubic feet per minute, and of this sum about 88 per cent would be the diluted sewage. (Witness does not take into consideration the Lake Michigan water entering into the sewage.)

2150 I believe that at times the contamination of the water supply of Chicago, at the intake cribs of said city is appreciable. (Objected to by Mr. Todd and Mr. Johns.) Assuming that an epidemic of Asiatic cholera should occur in the city of Chicago, under existing conditions it is possible that the germs of that disease might find their way into the intake tower of the St. Louis waterworks, because I do not believe there are any existing artificial or natural agencies which would, at all times, insure the prevention of these germs reaching the intake.

2151 I believe I have stated that the banks of the Mississippi river from Grafton to the mouth of the Missouri are straight, barring certain sinuousities—I forget just the expression which I used. I know that the channel does change from side to side a number of times during that reach of the river, as I recall it, some five or six times, passing from a position near the right bank to a position near the left bank. As to the effect which this changing channel would have on the mixing of the water, I believe that it would tend to assist the mixing of the Illinois river water with the water of the Mississippi river, and that a greater mixture would naturally occur than if the channel formed a perfectly straight

line during that reach. I stated that the Mississippi river had two sharp bends in it between the mouth of the Missouri river and the Chain of Rocks intake tower and I believe that just as these bends would tend to increase the mixing or commingling of the waters of the Mississippi river with the water of the Missouri, so it would tend also to mix the waters of the Illinois river with the waters of the Mississippi and with those of the Missouri river. Speaking as an expert, I do not think it is possible for the Illinois river water at all times to flow from Grafton to the Chain of Rocks, and by the Chain of Rocks without some of it reaching the intake tower of the St. Louis waterworks.

2152 Assuming the minimum stream flowof the Mississippi river at the Chain of Rocks is at times as low as 40,000 cubic feet per second and assuming that the flow of the Chicago Drainage canal is increased in the future from 5,000 cubic feet per second to 10,000 cubic feet per second, it is my opinion that under the increased conditions of flow there would be a material increase in the liability of infectious material to reach the intake tower of the St. Louis waterworks from the Drainage canal.

MR. TODD: I object on the ground that the facts assumed have not been proven and that this is not re-direct examination.

I should say that the conditions assumed in the last answer would tend to increase the proportion of Illinois river water which would become mixed with the water of the Mississippi. (Same objection.) (Question asked giving results of analyses of three different samples of water.) If these three samples are supposed to represent different mixtures of pure water and sewage, I should think that so far as dilution alone is concerned, sample No. 1 contained the least sewage, sample No. 2 contained more than sample No. 1 and less than No. 3 and that sample No. 3 contained the most, speaking solely with respect to dilution.

2154 On the basis of the chlorines, I would say that the relative dilution of sewage in the three samples is as to the

amount of chlorine in each, which were 6 in the first sample, 16 in the second and 26 in the third, that would not be an exact ratio, but for practical purposes it would give us the desired result. If informed that the first sample represents Chicago water from the tap at 2421 Dearborn street, and that the second and third samples represent water taken from points on the Illinois river, since I was interpreting the results simply from the standpoint of a water analyst and under the assumption named in the previous question, it would make no difference where the samples came from. If water of the character of sample No. 1 has been the cause of typhoid fever, and if this sample be compared with samples Nos. 2 and 3, which, according to the analyses and the previous assumptions indicate a less degree of dilution with the sewage, it would be my opinion that there would be more chances of samples 2 and 3 causing typhoid fever than sample No. 1 so far as dilution is concerned.

2156 It is my judgment that the water of the Mississippi river below the mouth of the Illinois and above the St. Louis waterworks intake is less valuable for drinking purposes now that before the opening of the Drainage canal January 17, 1900. (Objected to for the reason that the value of the water prior to the opening of the Canal has not been proven nor witness has not shown his knowledge thereof.)

RE-CROSS EXAMINATION by Judge Johns:

Supposing that the current of a stream in its deepest part runs close to a precipitous curved bank of a river at the rate of three miles an hour when it comes to a point where the river is again straightened—or, in other words, assume a condition where there is a curve, followed by a straight stretch and where the current at the curve is near a precipitous bank, it might follow along the straight reach and on the other hand it might be deflected to some extent across the stream again. It is possible it might be either of those things—there would without doubt be a slight deflection, that would be the natural condition.

2157 I do not believe that it would keep exactly to a straight line along a straight stretch under the assumed conditions of a uniform cross-section. I have not been on the Mississippi river between the Chain of Rocks and Grafton. I derive my knowledge of the banks and curves and reaches of the Mississippi between the Chain of Rocks and Grafton from several maps, among them the Government charts and charts of the Mississippi river commission.

2158 I don't recollect the date of these maps. They were the same charts which I examined with reference to the cross-section for turbidity for my examination in chief. I don't think any of these charts were within the last ten years. I think they were made along in the 80's. I do not know whether these charts represent exactly the condition of the banks and curves of the Mississippi river in January, 1900. I understand that the banks of the Mississippi do change from time to time, sometimes rather suddenly, due to the variations in the flow of the stream—due, perhaps, to the cutting away of some of the banks, the cutting away of the bank might be caused by a change in the direction of the current or in the amount of flow.

2159 My knowledge of the probability of the waters of the Illinois reaching the intake is not derived from a personal inspection of the river, but from various maps and charts which were made from 1870 to 1880. Assuming that the volume of the Illinois river at Peoria before the opening of the canal given me, namely 40,000 cubic feet per minute, is the lowest known stage of water of the river at any time within the last 25 years, that assumption would be fair upon which to make a calculation of the percentage of dilution with reference to that particular time. I could form simply an opinion of the dilution at the time the figures were given.

2160 I know of no exact requirements of scientists as to the dilution of sewage with good water so that the water might be used with safety. I prefer the word "safety" to "potable" because the word "potable" in testimony does not con-

vey to my mind a definite meaning. Water polluted with sewage can be diluted to such an extent that the chance of contracting disease by drinking the water is very remote.

2161 The greater the dilution the less the chance of harm, so far as the dilution goes.

Q. Assuming that the city of Chicago had for fifteen years prior to 1900, discharged into the Illinois and Michigan canal substantially the same amount of sewage that has been discharged by the Drainage canal into the Illinois river since 1900, with a dilution of only 40,000 feet per minute, would you think that that sewage had, during that fifteen years, reached the intake at St. Louis? Objection by Mr. Jeffries.)

Q. I just want to know whether if it goes into 40,000 feet of dilution in the Illinois river, it is just as likely to reach the intake as with 300,000 feet of dilution?

A. I understand that you made no comparison; I understood you to ask if it did? Q. Yes, sir.

A. And I believe that so far as dilution goes, it might.

Q. Well, if the waters of the Illinois river, to which are added 300,000 feet of water from Lake Michigan, certainly reach, in your opinion, the intake at St. Louis, why wouldn't the waters of the Illinois to which were added 40,000 feet, as certainly reach the intake at St. Louis?

A. I think that so far as dilution alone is concerned, they might as certainly reach, so far as dilution is concerned.

Q. But if for 15 years prior to 1900, substantially the same amount of sewage discharged into the Illinois river from Chicago, diluted with 40,000 feet of water as is discharged since 1900, diluted with 300,000 cubic feet of water, then the danger of disease in St. Louis from the sewage of Chicago, diluted with 40,000 feet of water, would be more than seven times as great as if diluted by 300,000 feet of water, would it not?

MR. JEFFRIES: I object to that question for the same reasons stated in my objection to the previous question.

A. In so far as dilution itself is concerned, that would practically be the case, so far as dilution itself is concerned;

dilution is a good thing. I do not know whether there ever was any Asiatic cholera in Chicago.

2163 As to whether Chicago might have an epidemic of Asiatic cholera would depend wholly upon circumstances. If our health officials in most of our cities, particularly the seacoast cities of this country did their duty, this country ought not to be visited by cholera, but I cannot say and no one can say when cholera might not occur in this country. When I say that the pollutions in the Illinois river are sometimes appreciable at the intake, I mean that if the Illinois river is polluted that that pollution may reach the intake, at the Chain of

2164 Rocks, but I cannot state the extent to which it would reach the Chain of Rocks, or when it would. I cannot say whether it would at all times. As a general rule, typhoid fever comes in the early fall in this hemisphere. I could not say definitely whether the pollution in the Illinois river was appreciable at the intake, in the fall of 1902. By appreciable, I mean that it may have an effect upon the health of the people who drink the water. I cannot say that it does, as a matter of fact, have an effect upon the health of the people, but I believe there is a possibility that it might.

2165 I do not know that the waters of the Missouri river have an appreciable effect upon the character of the water at the intake, but I believe that they may. I attribute the extraordinary amount of matter in suspension in the waters of the intake to come largely from the Missouri river. If there were typhoid fever germs reaching the intake on a certain date from the Missouri river, and if there were others reached the intake from the Mississippi river and others reached it at the same time from the Illinois river, and if these germs caused typhoid fever in the city of St. Louis, I couldn't say exactly which one of the three or whether all of them caused the typhoid fever, and I couldn't tell the relative number of cases which each one caused without knowing more about the number of germs that came from each one. If, under the conditions supposed in a former answer, the typhoid germs from the Missouri river traveled

forty miles, those from the Mississippi 100 miles and those from the Illinois 350 miles and supposing that the time of transmission to St. Louis was proportionate to the distance named, so far as that fact alone—disregarding everything else and disregarding the numbers and those other factors, and considering the question of time, why, those nearest might be con-

2166 sidered as having the greatest effect, but in making a true comparison, you would have to compare all factors.

2169 In regard to the questions asked me in relation to sample Nos. 1, 2, and 3, supposing sample No. 2 was taken above Peoria and represented fairly the quality of the water at that point at a given time, by the time that water reached Grafton, I should suppose that it would be changed, under existing conditions. The process of nitrification would practically have changed it to some extent. It would have changed it for the better. If sample No. 3 was taken below Peoria, the same conditions would apply to that. If after the arrival of these two conditions of water thus improved, they were added at Grafton to the Mississippi river in the proportion of 1 to 7, at the time they reach the intake, they would be changed, as far as nitrification is concerned probably.

2170 I suppose that process might keep on, in the Mississippi river to some extent. They would be changed by dilution. After the mixture of the water of the Mississippi river, the resulting water would no doubt be quite different from that in the Illinois river. I could not say from these anaylses whether either one of these samples are positively bad and unsafe for drinking purposes. I could not say whether they would produce typhoid fever or other disease.

2171 RE-CROSS EXAMINATION by Mr. Todd:

I could not say exactly what proportion of the 300,000 cubic feet of water that is passing over the Bear Trap dam at present, is sewage and what proportion is Lake Michigan water.

2173 When I stated that 88 per cent of the flow at Peoria was made up of Chicago Drainage canal water, I figured on 300,000 cubic feet from the Drainage canal and 40,000 cubic feet from the Illinois river, but I cannot tell you the exact proportions of Lake Michigan sewage in the water. In the samples known as Nos. 1, 2 and 3, I could not tell whether those samples indicate sewage pollution without regard to anything else. I should want to know the character of the water, the character of the so-called pure water with which the sewage was supposed to be mixed. I should desire to know something about the bacteria present, the abundance of bacillus coli, and the color and odor of the water may be of some assistance.

2174 I was able to make a comparison between those samples in regard to the diluted sewage contained in each, because they were assumed to be a mixture of pure water and sewage and I was simply asked to compare one with the other.

2175 Q. If three samples of water, such as you have testified to, should be presented to you and your analyses should disclose ingredients such as have been assumed to exist in these three separate samples, and your opinion was asked as to whether those samples were sewage polluted or not, what answer would you make?

A. I could not be able to tell definitely from these. I could give some idea possibly as to the relative probability, but I could not give what I would consider a definite answer from these analyses.

Q. Could you give any scientific opinion based upon these analyses alone?

A. Based upon any one of these analyses alone, without considering anything else than the figures here shown; and without knowing the source from which they came, I couldn't state definitely that these were samples of sewage pollution if I knew absolutely nothing about them aside from these figures. There is nothing in either one of those samples which would indicate that if a person took into his system water chemically

similar to either one of those samples that he would contract typhoid fever. There is nothing connected with the analyses of these three samples that would indicate typhoid fever.

2176 The germ of small pox is not transmitted by water. The same is true of scarlet fever. When the assumption was made that sample No. 1 referred to would cause typhoid fever in Chicago, there was nothing in the sample indicated that such a condition would obtain. Without any assumption that these three samples were all mixtures of pure water and sewage I could not say, from samples Nos. 2 and 3 that they contained sewage. Assuming that the water at Grafton, in 1899 prior to the opening of the canal, was condemned by the St. Louis Health Department as being not potable, the entrance of the Drainage canal into that water would render that water less valuable for drinking purposes. It is a case of relative conditions.

2178 If water had been declared absolutely unfit for drinking purposes, I should consider that, from a sanitary standpoint, it had a very low value. If I could not get any other kind of water I would give some value to that water. Assuming that the city of St. Louis is so situated that it could get other water, and that the water of Grafton in the Illinois river by the analyses of the city chemist in 1899 was condemned and pronounced dangerous to the public health of the city of St. Louis, what value would you give to that water?

A. If it were really dangerous to health, I should give it a low value.

2180 As I understand it, there is a greater possibility today of the water supply of the city of St. Louis at the intake being polluted than there was before January 17, 1900, by reason of the discharge of the sewage of Chicago through the Chicago Drainage canal.

That probability has been demonstrated within the bounds of scientific judgment; it has not been chemically demonstrated. I have no information that leads me to believe that it has been chemically demonstrated excepting that I understand that certain results of the analyses in general show slight increases in the organic matter, etc., indicating of itself, but not proved. I

do not consider that these indications rise to the dignity of proof. I don't believe it has been chemically or scientifically proved that the waters that enters the intake tower today are more injurious to public health than they were prior to 1900. I don't believe it has been chemically or scientifically proved, but I believe that scientific judgment leads us to believe that such is the case.

Q. When scientific demonstration fails to establish a fact then the so-called scientific judgment does not differ from the judgment of a man who is not scientifically advised, drawing his inference from the same conclusion?

A. Where an absolute scientific demonstration is impossible, the next best thing to my mind is a scientific judgment.

Q. Well, can a judgment be scientific when the facts upon which that judgment is predicated, are incapable of scientific demonstration? A. No, sir.

2182 If it could be proven to me that Asiatic cholera germs would not live longer than five or ten days in natural waters under conditions existing, my conclusion that they could reach the intake from Chicago would be changed, but I am not sure at all that the conditions existing in a laboratory experiment would be comparable to those which would exist in running streams.

2184 WILLIAM THOMPSON SEDGWICK, examined in chief by General Crow:

Am not a physician, have studied in a medical school but have no medical degree. Taught physiological chemistry at Yale for one year, etc.

2185 Am a biologist. Scientifically that term implies work upon living things which may be anything from man to microbes. It is a very general term and of course I do not pretend to be an expert in all its departments. Am now Professor of Biology in the Boston Institute. I am an epidemiologist. That term implies an expert knowledge of epidemics, their origin, their characteristics, their scope and everything else relating to them. I have made that branch of sanitary science as

related to American cities and towns and the American public, a study.

2186 Am a bacteriologist. Have taught and have had practical experience in that line. In the preparation of the paper I have mentioned on typhoid fever, in Chicago, in 1892, in a general way I had occasion to investigate the physical and sanitary conditions of Chicago with reference to water supply, sewerage and sewer out-falls at that time.

2187 I came to the conclusion mainly from a study of the typhoid fever statistics and the general arrangements of sewerage and water supply that the city was then suffering from one of the worst epidemics of typhoid that ever afflicted any American city and that this pollution was derived from typhoid cases in the city which contributed their sewage to the sewers of the city which emptied either into the Chicago river or into the Lake and in that way, gave occasion for the germs of the diseases to get into the cribs or the intakes of the water supply. I made no very thorough investigation of the Chicago river and its branches. I simply walked along the river at various points and noticed its condition—which was obvious to the eyes and nose. It was grossly polluted.

2188 Chicago sewers are built on the combined plan. This means that street washings and storm water find their way into the sewers and greatly accelerate the flow in the sewers, at the same time, diluting the sewage somewhat. This accelerates the flow and shortens the time spent in the sewers.

2189 I should say several hundred tons of sewage matter are discharged daily into Chicago sewers. The sewage from a quarter of a million of inhabitants goes into Lake Michigan. The remainder is discharged into the Chicago river and from that, into the Drainage canal.

2190 The effect of the sewage now going into the Lake is to pollute the waters in the vicinity of the intake cribs.

I recognize a difference between mere pollution and infection—or what I might call infectious pollution—somewhat as

follows: I understand by pollution alone, a condition in which water contains organic matters, or even filth, free from the germs of specific diseases; and I understand by infected water or an infectious pollution of water, or an infectious contamination of water, a condition in which, either with the same or more, or less pollution, the germs of specific diseases are present; so that a water may be polluted, from my point of view, but not infected, or it may be infected and yet to the ordinary eye not polluted. Water contaminated by infectious pollution is dangerous.

2191 Mere dilution will not destroy or eliminate infectious pollution or matter in water. On the basis of dilution alone, I do not consider that the sewage from the Chicago Sanitary district as it reaches the Illinois river above Peoria is at all times rendered pure and safe for domestic use. (Witness expresses himself at length on the question of self-purification of waters.)

2192 There is, at all times, in certain streams, especially, a large measure of self-purification. The subject is a complex and difficult one and the growth of opinion has been to increase our distrust in the efficacy of self-purification of waters or sewage.

2193 (Witness reads from his work on "Principles of Sanitary Science and Public Health.") (Motion to exclude by Judge Johns and Mr. Todd.) Sewage flowing directly from the out-falls of the city sewer will affect the value for drinking purposes of a running stream of water.

Q. State whether or not the sewage from a district as large as the Sanitary District of Chicago would affect the value for drinking purposes of a steam as large as the Drainage canal and as large as the Drainage canal and the Des Plaines river and Illinois river combined, and if so, in what manner?

A. Yes, sir, the mere introduction of sewage into a stream at once creates suspicion as to the—at once throws suspicion

upon the character of that stream, and unless it can be shown that that sewage has been effectually removed by puri-
2194 fication, the value of that stream is distinctly lowered. The water of the Mississippi west of the main channel of said river, below the mouth of the Illinois, is decidedly less valuable for drinking purposes now than it was before the sewage from the Sanitary District of Chicago was run into the Drainage canal and through it into the Illinois river.

The addition of such a volume of liquid as passes through the Drainage canal must materially—must often materially, quicken the flow of the Illinois river; it must therefore hinder effective sedimentation, and thus by shortening the time required for infectious germs to pass through the river, and by interfering with their detention, aggravate the danger of their arrival at the mouth of the river. I should like to say right here, that the time allowed in all these matters is very important, so that any quickening of the flow is a grave consideration. It is not so much distance as time which is the basis of self-purification of streams.

2196 By increasing the flow, sewage or infectious pollution from Peoria and the lower points on the Illinois, might arrive more quickly at the mouth of the Illinois and mingle with the waters of the Mississippi. The clearer the water—other things being equal, the slower the rate of sedimentation of bacteria. I believe that increasing the speed of the current of the Illinois, by the addition of the water of the Drainage canal, would have an effect in increasing the typhoid and liability to typhoid and other water-borne diseases, on the part of the inhabitants of Missouri using the waters of the Mississippi for drinking purposes, below the mouth of the Illinois. Speaking generally, the sewage from cities and towns renders unfit for drinking purposes the waters of a running stream for the purposes of domestic use.

2197 Settling basins alone—not considering anything else, are not recognized as an efficient and adequate means for the purification of sewage to be discharged in a drinking water

stream. As to the longevity of the germs of typhoid fever, as a general proposition, in connection with sewage polluted water, our ideas have undergone some change of late years. My ideas have undergone some change. The tendency has been to come to the belief, or has been to show or to indicate a greater and greater longevity. Laboratory experiments have sometimes indicated a short and sometimes a longer longevity. Practical experience has tended to make us believe in a greater longevity than that formerly entertained and having reference to the conditions in the stream, my belief is that in a sewage polluted stream, the typhoid fever germs might live, in gradually diminishing numbers, for weeks or months or even years.

2198 Assuming that the bacillus coli communis is not found in greater numbers in the Illinois river now, than before the opening of the canal, I do not consider that the water is at all times no more dangerous for drinking purposes than formerly. Bacteriological examinations cannot be made at every moment and are at best not absolute guides as to the sanitary condition of the water. Assuming that germs of typhoid fever coming from the sewers of Chicago, might be in large numbers deposited in the bed of Lake Peoria, for the period of a month, I do not consider that typhoid germs would be entirely destroyed at the end of that time. Assuming that typhoid germs coming from Chicago are deposited in large numbers in the lakes and slack water portions of the Illinois river above Peoria, I think at times that flood conditions such as would scour the deposits from the bed of the stream would cause the water leaving Lake Peoria to contain at times more infectious and dangerous pollution than is at present in the diluted sewage entering the Des Plaines river at the Bear Trap dam.

2199 The removal of deposits of sewage matter from the beds of streams has resulted in causing typhoid epidemics. (Refers to the old case of St. Clair river.) I do not consider that the water of the Illinois river, since the opening of the Drainage canal and now, as it enters the Mississippi river, is one which may be used with safety for drinking purposes.

Q. Now, Professor, assuming that the only pollution of the Illinois river was that contributed to it by the Chicago San-

itary District, and having in mind the large amount of typhoid fever in said district, do you, or do you not consider the effects of the time interval, dilution and sedimentation occurring between Chicago and Grafton, would be such as to render the waters as it enters the Mississippi at all times free from liability of producing water-borne diseases in those who drink it?

A. Emphatically not, for the reason that such processes of self-purification, including sedimentation and dilution, as would take place in the Illinois river and above, to Chicago, would be, in my judgment, inadequate to insure at all times and seasons a complete removal of infectious material.

2200 (Refers to the Lowell, Mass., epidemic. Says it was caused by Stony Brook stream running into the Merrimac at right-angles.) Stony Brook stream was much smaller in proportion to the Merrimac than the Illinois is to the Mississippi.

2201 This infection came a very short distance up Stony Brook. It entered the Lowell waterworks and produced an epidemic three and one-half miles below but there was also reason to believe that it reached Lawrence, nine miles further on. I believe that infected water coming from the Illinois river and entering the Mississippi would become mixed with the water so as to menace the health of the inhabitants of the Missouri shore using Mississippi water. I consider it probable that infectious pollution would, at times, enter the intake of the St. Louis waterworks.

2202 During a period of fifteen years prior to January 1, 1900, typhoid fever death rate in St. Louis has not in general been above that of some cities provided with water supplies considered pure and of good repute. Beginning with January 1, 1900, there has been a marked annual increase in the typhoid fever death rate of St. Louis so that it has, during that period, not only been higher than during the previous period of five years, but also higher than at any time in its own history since 1885 and very much higher than the death rate in Boston, with which it previously compared very favorably.

2203 Assuming that the only pollution on the water-shed of the Mississippi and its tributaries, above the intake of

the St. Louis waterworks, was that derived from the Sanitary District of Chicago and having in mind the large amount of typhoid fever in Chicago, I believe that infection and dangerous pollution might find its way into the water supply of the city of St. Louis.

2204 Under the same assumptions I believe that typhoid fever germs from that district are liable to find their way into the water supply of St. Louis. (Witness states that experiment made with 107 barrels of bacillus prodigiosus shows that typhoid fever germs can be carried down the canal, the Illinois river and to the intake.) Assuming that an epidemic of Asiatic cholera took place in Chicago, it is possible that the germs of the disease might find their way into the intake of the St. Louis waterworks.

2205 (Recounts details of Plymouth, Penn., epidemic in 1885.)

2206 (Same as to the Lowell, Mass., epidemic. Gives details of Newburyport epidemic. Newburyport is at the mouth of the Merrimac river.)

2207 The cause of this epidemic was the drinking of water from the Merrimac, which had been infected at Lowell, 25 miles away. The Rivers Pollution Commissioners of Great Britain in the report published by them in 1874 state that there is no river in the United Kingdom long enough to purify itself from any sewage admitted to it, even at its source. That stands as one of the axioms of sanitary science today.

2208 The epidemic at Windsor, Vermont, was caused by one case of typhoid fever on the water-shed above, not very far above, a mile perhaps. In 1898 I made a special study of typhoid fever in Pittsburg. They drew their water supply from the Allegheny which is a swift stream with only remote pollutions. A study of conditions there resulted in recommending the filtration plant for the city of Pittsburg, for the reason that in my judgment, infectious materials might be brought to cities which had no filtration plant, from points as distant as Oil City or even more remote—113 miles or more.

2209 The epidemic at New Haven, Conn., occurred about 3 years ago. It was caused by feces washed from a house on the water-shed where there had been a few cases of typhoid

fever. The epidemic at Ithaca, New York, we have every reason to believe that the conditions were quite similar to those at Plymouth, and New Haven.

2210 (Refers to epidemic at Hamburg, Germany, in 1892, and the breaking down of the Berlin, Germany, filters, which caused a small epidemic of typhoid fever.) It is a matter universally admitted among sanitarians that running water uncared for and unprotected by special processes of filtration or prolonged and very thorough storage, is liable, if from an infected watershed, to convey the germs of disease. I found in Buffalo, rather to my surprise, a feeling prevailing among medical men that the time was at hand when Buffalo had got to purify her water because of the pollutions put into the lake at Cleveland and higher points.

2211 I think it is a great question whether the people who are using the big lakes have not got to give up the use of them after while. A while ago, Professor Jordan reported practically to that effect for Chicago, and Detroit certainly stands in great danger from pollutions at Port Huron and possibly other points. Cleveland I have been told, although I am not sure of this, is seriously thinking of giving up its tunnels and going into filtration because the water that comes down from above is polluted. It was one of the commonest things that chemists and sanitarians believed and they had reason to believe at that time—that running water, at even modern distances, would so purify itself as to be safe. But Pittsburg, Lowell and Lawrence, and so far as I know, nearly all of the cities that have trusted to that, have been typhoid ridden and today, as I reported at Pittsburg, the distance of 100 miles, or even more remote points may produce typhoid fever. It is not today so much a question of distance. It is the question of giving time for the germs to settle out and die out and it is dilution and time of quiesence, particularly quiesence.

2212 Q. Professor, would the amount of infectious pollution affect the question of time needed, or the degree of danger?

A. It affects the degree of danger. It would not affect the time; that is the time for each individual microbe; of course

that is its own individual problem. One microbe coming down from Chicago and resting quietly in the slack water of the Illinois, if it lay there long enough would probably die out—I would say, must certainly die out if it lay there long enough. Of course, someone might not agree with me on that, but I think so; but of course, if a million came down, the chances that some might be carried on by a little freshet or something of that kind before they had died out—for they don't all die at the same time—would be greatly enhanced, and other things being equal, the larger the infection, the more serious the danger.

2214 After a careful consideration of the subject I can say that in my opinion, beyond a reasonable doubt, the principal portion of the increase of typhoid fever in St. Louis, since January 1, 1900, of the principal annual increase, since January 1, 1900, has been due to the pollution of the water supply of St. Louis by the sewage of the Sanitary District of Chicago.

2215 I stated this morning that from 1895 to 1899 the typhoid rate in St. Louis was substantially normal, comparing favorably with similar cities of like situations and of similar size. I should like to add that the word "normal" must be taken in a general rather than in an advanced sanitary sense, for I believe that both Boston and St. Louis are capable of further improvement in this direction, and both are higher than New York and London. From 1895 to 1899 the death rate from typhoid in St. Louis compares favorably with that in Lowell after the introduction of the ground filter water supply. I have no experience that would cause me to believe any running stream can be relied upon, at all times, to remove disease-bearing germs, such as the typhoid bacillus, if the pollution was at all serious or extensive.

2216 The opening of the canal has resulted in the addition of an amount of lake water which will yield 5,000 cubic feet a second at Lockport, passing out of the canal, and this, on the face of it, adds a purer water than that sewage. The sewage is unquestionably diluted, as is shown by the improved condition of the Chicago river, but this water is drawn from the

mouth of the Chicago river and vicinity and that water has long been known to be infected more or less. The problem then resolves itself into this—does the dilution of a presumably often infected sewage, by a presumably often infected water contribute to the purity of the Illinois river? But that is not all. The Chicago river was formerly a sluggish stream. Today it is much less so, and those infectious materials that were formerly put into the Chicago river are today carried with comparative swiftness down the Drainage canal and into the Des Plaines and Illinois rivers. We have further, then, to consider whether sewage, as described above, carried quickly, and in considerable volume, into the Illinois river, does or does not render that river safer than before. My only belief based upon those considerations which I have already outlined in regard to time as a purifying factor is that it is at least very doubtful whether the pouring of the sewage of Chicago, diluted as described, into the Illinois river does at any time improve that river. Looking at it still more closely and considering the larger amount of sewage now delivered, the opportunities for sedimentation, the susceptibility of the Illinois river to
2217 freshets, large and small and in view of the changed conditions brought about by the introduction of this fresher sewage with a larger volume of water, I am inclined to believe that—and further, in view of the frequent extensive pollution of the sewage of Chicago by the germs of typhoid fever.

Q. You mean infection, don't you?

A. Infection of typhoid fever, I should say—I am inclined to believe that the pouring of the sewage diluted as described, into the Illinois river, has not at any time improved it from a sanitary point of view—from the point of view of the health of the people who may use that water on the Missouri shore. I may say that undoubtedly at times it may have improved its appearance, and may seem to have improved its quality; but taking it through the year at all times, at all seasons, I am inclined to doubt exceedingly such improvement—any such improvement at any time. I believe that the danger is contsant, immediate and continuous on the part of the inhabitants of Missouri using the Mississippi river water, by reason of the sewage

from the Chicago Drainage canal infecting the water of the Illinois river. (Witness states reasons.)

2218 Dams undoubtedly, so far as they produce slack water or quiesence, favor purification and the disappearance of disease germs for the time being, but if the sediment or sludge is allowed to remain in the stream and is not removed artificially, the chances are good and experience shows that in freshets, it may be returned to the stream and again become a part of it, travel with it and produce trouble below.

2219 The only safeguard is to keep the germs quiet in the sediment at the bottom so long that they shall have entirely died out. We hardly ever know when that is. It is a very weak reed to lean upon. At Lawrence there is a big waterpower supplying immense amounts of machinery with power to run. At times the water reaches back almost to the Lowell sewers—nearly nine miles, and the dam above Lowell, which furnishes the power to Lowell reaches back almost to Nashua, New Hampshire—sixteen miles. The Merrimac in the summer, is a series of mill-ponds, slack water like that, the water used for mill power.

2220 In time of freshets we get our epidemics—when the freshets come down the river and scour it out. We do not have a high typhoid rate in summer when the dams are effective and sedimentation is going on. We get it in the spring, when the pollution is great and the scouring is also great. We also get epidemics in the autumn or after the autumn rains. Lawrence immediately set to work and put in an intermittent sand filter and Lowell put in driven wells. Both are now among the cities having entirely reasonable death rates from typhoid fever. My opinion is that the rate of growth in the Chicago Sanitary District is likely much to exceed, and the total growth is likely greatly to surpass that upon the water-sheds of the Des Plaines, Illinois, Mississippi and Missouri and their tributaries.

2221 I should expect it to be at least ten times as great. I will add to this answer, basing an opinion upon pages 119 and 121 of the Illinois State Board of Health report for 1901, sanitary investigation of the Illinois river and tributaries, I should even be willing to make this figure very much larger,

as the increase in rural population given there is less than one per cent; that in urban population outside the Sanitary District of Chicago is 28.2 per cent, and that of the city of Chicago is 54.4 per cent. The urban population as compared to the rural population in this country is increasing very much faster. Now it is one of the most striking facts with which sanitarians have to deal, that villages are growing into towns; towns into cities; water supplies and sewerage systems are being introduced and in consequence of this growth, problems of water supply and sewage disposal are almost everywhere becoming common and pressing. This condition of things is bound to increase. In the older cities, it has already led to serious investigation and litigation, with long and varied attempts at remedial legislation, and I cannot help feeling that with the impending growth of cities and towns in the Mississippi valley, it is a question of the gravest sanitary consequence what becomes of the sewage of the cities and towns in that valley—in or near that valley—and also how their water courses may be kept from pollution and the dangers of infection. (For answer of witness as to effect of increase in population in Chicago to 5,000,000 people, with conditions as they are now, see record, pp. 2221, 2222 and 2223.)

2224 I consider that the Illinois water polluted and infected by the sewage from the Sanitary District has rendered less safe the water supply of St. Louis as drawn at the intake, for the reason that I believe the germs of typhoid fever may and do find their way through the intake into the water supply of St. Louis. Assuming that the population of Chicago Sanitary District covers 3,000,000 people and that the flow through the canal reaches 600,000 cubic feet per minute, I believe that the water of the Illinois river would be less pure and less wholesome as compared with that water at its mouth as found during the past three years. The danger of infection would be increased. If the population of the Sanitary District was increased to 5,000,000 people and the flow of the canal reached 1,000,000 cubic feet per minute, I believe that the water of the Illinois river at its mouth would be less pure, less wholesome and more infectious and less suitable for drinking purposes as

compared with the water at that point as found during the last three years.

2225 I believe that a mixture of the Illinois and upper Mississippi river water during their flow from Grafton to the Chain of Rocks takes place at times, such that the water of the Illinois river may find its way to the intake of the St. Louis waterworks. Assuming that sewage from 1,500,000 people living in the Sanitary District should be discharged into the Drainage canal, thence into the Des Plaines and Illinois rivers, Chicago being situated 358 miles from the St. Louis intake, and assuming that a typhoid fever epidemic of extraordinary proportions should become prevalent among the residents of the Sanitary District of Chicago at a time when the sewage from said district is being so discharged into the canal, I believe that such an epidemic would be likely to produce an epidemic of large proportions among those people living on the Missouri side of the Mississippi river below Grafton who use the waters of the Mississippi for drinking purposes. The citizens of St. Louis and the Missouri shore would have a right to regard themselves as in a critically dangerous condition as far as their water supplies were concerned.

2226 The same would apply to an epidemic of cholera. (Witness states that there will come a time when the rivers will get so sewage polluted that mere filtration will not suffice. It will be increasingly difficult to secure good water and to get rid of the sewage, etc.)

2227 Stream flows, in general, will not increase, but rather decrease as time goes on.

2228 (Offers in evidence, certificate showing number of deaths from typhoid fever in St. Charles, Missouri, from July 1, 1899 to January 1, 1903.)

2229 (Same as to city of Davenport, Iowa, from 1893 to 1902, inclusive. Same for Rock Island by months from 1893 to 1902. Same as to Moline, Illinois, from 1893 to 1903. Galena from 1893 to 1903. Warsaw for year 1902.)

2230 (Same for Kansas City from 1893 to 1902; St. Joseph, Missouri, Council Bluffs, Iowa; Omaha and Lincoln, Nebraska, and Chicago.) In regard to my testimony taken

yesterday, I will state that the quickening of a stream by the addition of a volume of other water, especially under conditions such as prevail on the Illinois, is a very serious menace to the people of the regions below who use that water. It is my opinion that in spite of the addition of the so-called "pure lake water;" in spite of the greater dilution resulting from that, the water of the Mississippi river is constantly and beyond all reasonable doubt rendered more dangerous to the public health and to the citizens who use it, because of that addition, and under all the circumstances which exist on the Illinois and Mississippi rivers.

2231 The Lowell epidemic of 1890 was caused by the dejecta of one person infected with typhoid fever, contaminating Stony Brook about three and one-half miles above the intake of the Lowell waterworks.

2232 The New Haven epidemic was caused by the dejecta of two or three cases of typhoid in a family living upon the watershed. Their dejecta were thrown out on the ground near by and in the thaw which I described yesterday, were washed into the stream. I think they were quite a little distance from the stream, perhaps 50 feet or something like that. It went only two or three miles down the stream, something like that, and from the stream into the reservoir where it underwent probably a very slight sedimentation. In the Windsor, Vermont, case the infection came from about a mile, from a storage reservoir and were supposed to have been washed into a very small stream—a mere thread of a stream.

2233 In the Newburyport epidemic the pollution was derived from the regular typhoid fever in the city of Lowell. The germs were carried down past Lawrence to Newburyport.

2234 At Zurich, Switzerland, the typhoid fever in 1885 was attributed to disturbance of sediment near an intake pipe and a defective filter.

2235 As a general proposition the urban population is very much more dangerous, very much more efficient in the pollution of the waters than a rural population. It would

probably be fair to say that the urban is at least ten times as dangerous. The reason for this is that urban populations are more often sewered and when not sewered, are more often upon streams. The opening of the canal, which has been brought about by cutting through the natural divide between the watershed of Lake Michigan and the Illinois river, has added to the drainage area tributary to the watershed of the Mississippi river as it flows to the intake tower, 63 per cent of the entire urban population; 63 per cent has been added to the amount above the St. Louis intake.

2236 Exclusive of the Sanitary District of Chicago, of the population of the watershed of Lake Michigan, I find the amount of urban population on the watershed of the Mississippi and its tributaries, the Illinois, Missouri and Des Plaines and their tributaries above the intake of the St. Louis waterworks, on the basis of cities and towns by 4,000 inhabitants and more, to be, 2,695,782. According to the 1900 census the population on the watersheds mentioned would be as follows: Missouri river, 1,090,832; Mississippi river above mouth of the Missouri, exclusive of the Illinois, 1,219,645; Illinois river, 385,305. All those added together make the sum I gave you a moment ago.

2237 The mouth of the Lowell sewers is about 9 miles above the intake of the Lawrence waterworks. From that point the water was pumped to the reservoir of the city of Lawrence where it was kept for a period varying from one to a little more than two weeks. If we add to this the time spent in flowing the nine miles we may say that the period of time required for water containing typhoid germs to pass from the Lowell sewers to the Lawrence water consumers was sometimes probably as long as 14 days or more.

2238 Settling basins holding suspected water for longer periods than this one at Lawrence have failed to protect the people using such water from typhoid fever. At Covington, Kentucky the water of the Ohio river more or less polluted on the stream above is kept at times as long as 32 days and yet Covington suffers severely from typhoid fever apparently due to infected water. At New Albany, Indiana, the same conditions exist. The typhoid at Niagara Falls is attributed by every

one who is familiar with the facts, to the sewage of Buffalo, although that sewage has passed down a stream one of the most favorable in the world perhaps, for dilution, aeration, oxidation, self-purification and similar processes. I consider the case of Niagara Falls as it is today, one of the most instructive we have. The sewage is well diluted, well aerated, and that for a considerable distance. The distance as I recall it between the sewers of Buffalo and the intake at Niagara Falls is about, I should suppose, 18 miles. It may be only fifteen. (Hypothetical question assuming certain numbers of cities to be situated on the watershed of the Missouri river, giving population, number of deaths from typhoid fever per year, number of miles from St. Louis, and stating that the sewers of all such cities discharge their sewage into the Missouri river, also assuming the same as to the Mississippi and Illinois rivers, and ending with, "State what, in your opinion the sewage from 1,500,000 people of Chicago had to do with the increased death rate from typhoid fever in St. Louis as above stated?")

2249 (Objected to by Judge Johns and Mr. Todd.)

2250 After having carefully considered the question and the assumptions which it contains, I believe that beyond all reasonable doubt the principal factor of the annual increase of typhoid fever mortality of the city of St. Louis since January 1, 1900, has been due to the pollution of the water supply of the city of St. Louis by the unpurified sewage of the Sanitary District of Chicago. In fixing this increase in typhoid in St. Louis I used the method known as that of "mortality percentages" in which the typhoid fever mortality is compared with the total mortality of any given district. Measured upon this basis, the typhoid fever mortality during the years 1901, 1902 and 1903 as compared with that during the years 1895, 1896, 1897, 1898 and 1899 was 73 per cent in St. Louis.

2251 Assuming the same state of facts as embraced in the last hypothetical question and considering in addition thereto the rural population of the watersheds of the rivers mentioned therein, my answer would not be materially modified for the reason that as I stated this morning the wastes of

rural life are, speaking broadly, usually disposed of satisfactorily from a sanitary point of view upon the areas within which they arise. Occasionally, of course, a rural contamination may produce an epidemic of typhoid fever, but such cases are infrequent and exceptional.

2252 The conveyance of water from the Lake Front of Chicago and from a population which I have already testified has been estimated at more than a quarter of a million people, now draining directly into Lake Michigan at the rate of 300,000 cubic feet a minute through an elongated conduit reaching from Chicago to the mouth of the Illinois river would, in my judgment, be a source of danger to persons using the water for drinking purposes on the Missouri shore and at St. Louis.

2253 I do not believe it is within the bounds of human possibility for any competent expert to say that in a period of low water in the Missouri river such as is likely to occur next Christmas time, a thaw on the Illinois watershed might not endanger the lives of people using the waters of the Mississippi below the mouth of the Illinois on the Missouri shore at the city of St. Louis by sending to them in that water, the unpurified sewage of the Sanitary District of Chicago. No competent expert either can or will say that any means exist at present by which such unpurified sewage can be warded off from the people on the Missouri shore and the citizens of St. Louis under those conditions.

2254 CROSS EXAMINATION by General Hamlin.

Am familiar with waterworks. Have given that matter some study. The system of purification I would recommend, where the water supply is taken from running streams would be filtration, in some cases, and storage in others.

2255 Storage is the accumulation of waters in great reservoirs so that it may be kept for some time before it is used without any treatment of it. The larger size the better. Filtration would be my judgment as the system for a city like St. Louis. I am of the opinion that there is more or less pollution in all running streams as distinct from infection and where sewage is carried into running streams then there is usually

infection. That in my judgment exists in the streams to which I have testified in this case, such for instance as the Mississippi, Illinois and Missouri.

2256 If the cities or towns below St. Louis on the Mississippi should take their water supply from the Mississippi river they would be affected by the sewage of St. Louis, if they took it unpurified. Unless the dilution was so great that the sewage of St. Louis was lost in the volume, I suppose that they would be affected. I attach much importance to dilution alone. It is a large amount of sewage that is discharged into the Missouri river and into the Mississippi above the mouth of the Illinois. If I were to eliminate all the sewage from Chicago and take the Illinois, with the Sanitary District out and its tributaries, and the Mississippi and its tributaries, and combine those waters as they are combined above St. Louis, I should say unhesitatingly that the water is and would be, under such circumstances, a polluted water, and that the chances are that it would be dangerous to the people of the city of St. Louis and the towns below.

2258 At the present time my judgment is that the best process of making this water a potable water would be by filtration.

Q. Well, then, so far as the purification of the water of St. Louis is concerned at present, and rendering it fit for domestic use here, for drinking purposes, the expense of doing that would be the same, whether the sewage of the sanitary district was in it or not, wouldn't it?

A. The probable cost of doing it at present, owing to the conditions on the various rivers and at Chicago would, I should suppose not be materially affected by the addition of the sewage of Chicago to the Mississippi river as those rivers are and as that sewage is today.

CROSS-EXAMINATION by Judge Johns:

I am not a chemist, but I regard myself as a bacteriologist. I consider the chemical examination of water of importance in determining its condition for drinking, under some, but not under all circumstances.

2259 A chemical analysis of the waters of the Missouri river at times might determine whether such waters are polluted

and at times it might not. The same answer would apply to the the Mississippi river.

2260 Sometimes I can determine from a bacteriological examination of running water whether it is polluted and sometimes I cannot. I could determine from my examination of the evidence as to the bacteriological examination of the waters of the Missouri whether the Missouri is a polluted stream but I very much prefer to do it in other ways. I could at times, I say, but when common sense comes in, I like to use that. I would make the same answer as to the Mississippi river and the same answer as to a joint consideration of chemical and bacteriological examination. A chemical analysis and bacteriological examination of the waters of the Missouri and Mississippi rivers I should not consider as competent at all times to determine the qualities of the waters for drinking purposes.

2261 I believe that waters of running streams, sewage polluted, purify themselves by the flowing of the streams to a large extent under favorable circumstances. The rapidity of the flow would have something to do with the degree of purification. It is the time factor which comes in and that would be profoundly modified by the rapidity of the flow. Numerous reaches where the flow of the water was extremely sluggish and occasional dams checking the water would contribute to the purification of it. Such reaches and dams would contribute to the purification by other means than sedimentation, by detaining the germs present and thus favoring their dying out if they lay there long enough to die out. Mere detention apart from sedimentation would be a factor in this time factor I have spoken of.

2262 If near a given river there were numbers of small lakes or ponds which filled up during the overflow or high water of the river and which contributed to the flowing stream of the river, when the water subsided, they would contribute to the purification of the stream in the proportion in which the supposed lakes and ponds afterwards contributed to the current of the stream. In times of flood, it would certainly contribute

to the purification of that part of the water which was over lakes. If there was a flod in the Illinois river in which the waters overflowed the banks and spread out in the bottoms which continued for four weeks and in the bottoms there is no perceptible current of the river those portions which stood upon the bottoms would certainly be purified somewhat. They would be purified so far as the sewage is concerned very considerably. I am familiar with the general physical characteristics of the Illinois river from studying maps and talking with men who have been up there.

2263 I understand that the bottom lands or the overflowed lands of the Illinois river are very considerable. The fact that the Illinois is a sluggish stream in its overflowed stages, that there are several dams and at times much so-called slack water, that in reaches of the river which are not affected by the back waters of the dams, there is in ordinary stages, in many places, and for long distances, a very slight fall, would aid in the purification of the waters of the Illinois river under ordinary conditions. The amount of dilution that would make sewage polluted water safe for drinking purposes is a pretty hard proposition. I do not think that I can answer that except to say that a very large dilution is required to make it reasonably safe. One gallon of sewage from Chicago to 100 gallons of good water would not make that water reasonably safe for drinking purposes. One gallon of sewage to 200 gallons of water I should not consider safe. I hardly know what to call reasonably safe.

2264 One gallon of sewage at Alton might pollute the waters of the Mississippi at the intake tower so as to make them unsafe for drinking if it was typhoid fever infected. (Same as to one gallon of sewage at St. Charles, Missouri.) Knowing that one gallon of sewage from St. Charles infected with typhoid germs had been put into the Missouri river, I should consider the water at the intake unsafe, as a general proposition, pro-

vided, of course that I did not know when that gallon was coming along.

2265 Assuming that I knew a gallon of sewage infected with typhoid germs was put into the Missouri river at St. Charles at a certain time and that I knew when that water would reach the intake tower, as a general proposition I would consider the water at the intake tower at the time of the arrival of this water from the Missouri as unsafe for drinking purposes. As to the same amount of infected sewage from Kansas City, which is between 400 and 500 miles away, I should not want to drink the water at that time when it was expected at St. Louis but I should not be willing to say, as a sanitarian, that that was unsafe for drinking.

Q. Then you are a little more particular as to yourself than as to the community in general?

A. No, but others are not as particular as I am.

Q. Well, having an equal regard for others, as for yourself, you would say that the gallon of sewage put into the waters of the Missouri at Kansas City, was unsafe, would you not, at the intake of St. Louis?

A. Assuming that the water was to be taken at the intake at the time that the arrival of that polluted water might be expected, yes, sir.

Q. If a gallon of sewage were put into the Missouri river at Omaha, Nebraska, and you knew when that water would arrive at the intake tower at St. Louis, would you consider that water unsafe for drinking purposes if the sewage were typhoid infected?

A. I don't know how far that is. It is farther away—it is six or seven hundred miles.

2266 A good deal would depend upon the flow of the Missouri at that time. If it were in flood, I should probably not consider that unsafe. If the Missouri was at its ordinary stage, I do not know whether I should consider it dangerous or not. I should have to think that over. I should want chemical and bacterial analyses of the waters and I should want to know con-

ditions more than I do now, the conditions of purification en route, etc. Taking my knowledge of the Missouri river and assuming that a gallon of sewage was put in that river at Omaha when the river was at its ordinary stage and that the sewage was typhoid infected sewage, when the water arrived at the St. Louis intake, I would consider that water unsafe for drinking purposes.

Q. If, in the year 1901 there were 13 deaths from typhoid fever at Lincoln, Nebraska, 58 in Kansas City, 6 in Omaha, 12 in St. Joseph, and 5 in St. Charles, and the typhoid bacilli in each of these cases, went by some means into the waters of the Missouri river, and some of them arrived at the intake in St. Louis, to which one of the six towns would you prefer to ascribe the bacilli arriving at the intake?

A. In answering this question I should have to say in the first place that I should not have any preference in the matter, except such as came from study of the facts laid down, and a weighing of the probabilities as to the origin of each of these—as to the part played by each of these. Other things equal, the nearer the infection, the greater the probability of derivation from that source. The question, however, is a very complicated one, inasmuch as it assumes a large number of cases in the upper regions of the river, and a small number at St. Charles, 47 miles away, as I believe. I should expect, as a result of the consideration of all the circumstances, that I should be entirely unable to assert any preference in the matter or to determine from which of these places the bacilli had come. If found, they would be more likely to have come from Kansas City, because that would mean 580 cases in Kansas City and 50 cases in St. Charles, in round numbers, assuming a mortality of 10 per cent and the likelihood of one getting into the intake at the Chain of Rocks would I believe be greater, all things considered, from 580 cases at that distance than from 50 cases at the other distance. It is a matter, however, almost entirely of guess work.

2269 Considering that Kansas City is 403 miles from St. Louis, I could not say positively that any of the typhoid bacilli

would arrive at all. I could not say positively that none would arrive. I don't know whether they would or not. I have an opinion and that is, that they would. The greatest distance that I now recall that typhoid bacilli have been transported by running waters and caused infection in some water supply is that of the Detroit epidemic in which it was apparently well established that the infection was conveyed for about 57 miles. The assumed and supposed distances, however, are very much more than that. For example at Pittsburg, I myself supposed and assumed that typhoid fever germs might have come as I said in my report, from Oil City, which was 113 miles, or even, as I remarked, from points much more remote. That is, there are cases on record where the sewage of towns above, apparently influences the typhoid death rate of towns below, and where no epidemic has ever happened or been traced, conclusively fastening the one upon the other.

In the present state of the subject I should not be willing to set any limit as to the distance typhoid bacilli might travel and at the end of their journey be of sufficient strength and vitality to communicate typhoid fever to people who drank the water.

2271 The real problem would be not so much the distance as the time. The Alleghany river is a swift stream—those 113 miles were covered quickly. It was a babbling stream most of the way, scouring the stones and while I was willing to believe that the typhoid fever in that case came as far as 113 miles, in another case with a slow stream I would not be willing to suppose that they had come fifty miles. I based my opinion that the typhoid bacilli came from Oil City on the rate of flow of the river largely and on my knowledge of the life history of the typhoid bacillus. There is such a thing as accurate and certain knowledge as to the life history of the typhoid bacillus in running water. I know, for example, that they may live to pass from Lowell to Lawrence—nine miles.

2272 In the Lowell and Lawrence case, the waters were polluted, all told, by about eight or ten cases.

Q. Well, your examination of the cases at Lowell and Lawrence excluded every other possible consideration of source of contamination than that which you discovered?

A. I tried to, and I believe I did.

Q. You didn't consider that it was possible that typhoid infected urine or dejecta might have been put in the reservoir or waterworks of either one of the places? A. No, sir.

2273 Assuming that some malicious person had injected typhoid bacilli into the reservoir at Lawrence or Lowell, which it is possible they might have done, those cases do not afford an accurate knowledge of the life history of bacilli.

2274 I wish to make it clear, however, that a malicious infection of the Lowell reservoir would not have invalidated my conclusion in regard to the Lawrence epidemic. From Lowell to Lawrence is 9 miles along the Merrimac river. The community living on the river is more densely populated than rural districts of Missouri. It is within the limits of possibilities that persons living near the Merrimac, between Lowell and Lawrence, might have had typhoid fever and that their dejecta might either be thrown into the river or washed in.

2276 (Witness is cross-examined as to the cause of the Lowell epidemic.)

2282 Q. In reporting upon the condition of affairs at Pittsburg and the remedy to be applied, did you exclude all considerations except the existence of the Alleghany river, and the flourishing towns above Pittsburg? A. I did.

Q. And without knowing whether there was typhoid fever in any one of those towns, or an excessive rate of typhoid fever in any one of those towns, you ascribed the typhoid fever in Pittsburg to the infection of the Alleghany river from towns above it?

A. I do not remember whether there was any or not; whether I based my conclusion upon that partly or not; but in any case even supposing there had been an excess up there, I should have come to the same conclusion, because they were pouring regularly a certain amount of sewage into the stream. All that is necessary to make the waters of a running stream

unsafe as to typhoid fever, is the fact that the sewage of populous places above is poured into the river, broadly speaking, without regard to the fact as to whether there is or has been typhoid fever in any of the populous places above where the sewage is poured into the river. In the epidemic at Detroit my knowledge is taken from books and publications and conversations. The St. Clair river is a passage way for the water of the three great lakes on their way to Lake Erie. I do not know that on each side of it there is a very flat country, full of marshes, that in these marshes and dwelling about them there is a large population of fishermen, that the St. Clair flats are dotted with clubhouses, the resort of all classes of people during certain seasons of the year. It seems to me that something of that kind was referred to in the paper which described the epidemic. I understand that the papers which described the epidemic and the persons to whom I talked, exclude all these considerations from the determination as to the cause of typhoid fever at Detroit. I presume they took the most easily ascertained and most prominent possible cause and ascribed to it and to it alone the entire increase in sickness, that would be good sense. I was perhaps a week in Chicago investigating the cause of typhoid fever. I made very little investigation except to study the general situation, but I secured the reports of the board of health and compared the typhoid fever death rate in Chicago with that in other cities. I also inquired into the water and milk supply and other possible factors and then bringing the results all together, arrived at my conclusion jointly with Mr. Hazen. I attributed

2285 the abnormally high death rate from typhoid in Chicago after excluding, as well as I could, other considerations, to the infection of the water supply by the sewage of the city. I discovered that typhoid fever had nearly always been very high in Chicago, that it never had what might be called an average rate of typhoid. At times, when it was lower than the general average of a series of years I ascribed the typhoid fever to occasional limited pollutions of milk supply, food supply, of the air and of the water and to some minor factors. When the

average rate of sickness in Chicago was less than the usual rate I did not attribute that solely and entirely to the infection of the water supply.

2286 When it rose above the average and far exceeded it, I attributed it to the water supply as a general proposition. The curve or line of typhoid fever in Chicago has been very irregular, always high as compared with cities having a very low, or as compared with most cities having purer water supplies, but occasionally rising rapidly to much higher points. I was led to believe that these rapid and unusual rises were due to the washing out of sediment from Chicago river into the Lake and an unusual contamination of the water supplies by such dislodged sediment or other fecal materials conveyed to the intakes.

Q. Did you compare the statistics, or examine the statistics as to the rain-fall in Chicago and find that such rain-fall was coincident with—or that the increase of typhoid fever actually followed a violent rain-fall, and a sudden rise in the Chicago river?

A. As I remember it, it did so in some cases, and enough to confirm us in the general belief.

If, by pathogenic germs you mean those of well defined infectious diseases, I never discovered such germs in running water.

2288 Water-borne diseases are such as are capable of being transmitted by water or which are capable of being conveyed from one person to another and from one community to another, by means of water as a vehicle. Typhoid fever and Asiatic cholera may be conveyed in this way. It is probable that some others may be conveyed in this way, but the evidence is far less clear than it is in regard to these two diseases. Asiatic cholera is an infectious disease, and it is believed may be

2289 communicated by the air or any of the other means by which typhoid fever may be communicated.

Asiatic cholera in Chicago is of very rare occurrence today, formerly, however, it prevailed very seriously in Chicago. I don't recall that it was ever serious or existed at all except in

1848 or 1847. Inasmuch as Asiatic cholera is by no means an exterminated disease, it might turn up in a population like that of Chicago at almost any time and the danger to the citizens of St. Louis under the existing conditions would be grave. The danger to St. Louis would not depend wholly upon the existence of Asiatic cholera in some one of the streams from which St. Louis derives its water supply. There would be danger of conveyance by train and in articles of merchandise but I should think that the most omnipresent—the most serious danger, would be from the water supply.

2290 The danger by train and by handling of merchandise must be added to the possible cause of typhoid fever anywhere. It is a possibility that a person in San Francisco whose hands were infected by typhoid fever germs, might arrive in St. Louis and spread the disease, or if he carried such germs in his clothes, or if some person packing goods in San Francisco should have typhoid infection on his hands, it might be communicated to people in St. Louis, New York, London, St. Petersburg, Moscow, Karthoum, by way of Moscow, and Nijni Novgorod. It might be conveyed as far as that, if he did not wash his hands en route. I see no reason, if he did not free himself from infection, why he might not convey it around the world. In a trip around the world, say in sixty days, I believe that they might convey it around the world and out of their habitat and away from anything in which they are known to essentially support themselves and that these germs would live.

2291 I should be unwilling to say that Asiatic cholera might not also be conveyed around the world under certain conditions, in other things than in water. Say, in clothes of persons traveling, or in merchandise that went around the world, and a great deal would depend, of course, upon the time and conditions to which the germs were subjected, but in the present state of our knowledge, I see no reason why they might not be transmitted even as far as that in those ways under favorable conditions, of course. A person traveling with ordinary speed around the world I should expect would leave some of the bac-

teria en route. I don't know that he would arrive with some of them. The chances are that he would not. If he was a respectable person and traveling around the world, he would probably take a bath and change his clothes.

The bacilli coli communis are common in the sewage polluted waters of Massachusetts, or some of them.

2292 There is no geographical limitation to the existence of bacilli coli communis in polluted waters, so far as I am aware. Whenever there is sewage polluted water, there either may be now or may have been the colon bacillus. It is not pathogenic in the sense in which I define pathogenic, although it is put down in some of the books as capable of producing disease.

2293 It is not the cause of a well-defined specific disease, nor is it, to my knowledge, the cause of ill-defined and general diseases. I do not regard the bacilli coli communis a standing or floating menace or any other kind of a menace to the city of St. Louis, in themselves, inasmuch as every citizen of St. Louis has millions of them in his alimentary canal. I do not intend to be understood as testifying that the bacilli coli communis in themselves were dangerous to the health of the city when found in the waters supplied to the inhabitants of the city for drinking purposes. In order to become of themselves a menace, they would have to be capable of producing disease. For practical purposes we may acquit the coli communis of being a pathogenic germ and I would acquit them in the Illinois river, of being pathogenic for practical purposes.

Q. Do you mean to say that the typhoid deaths of the city of St. Louis since the year 1900, considered annually are about 73 per cent increased over the deaths from the same disease before?

A. Not exactly that. What I did say was this: that the increase in the average percentage mortality from typhoid fever in St. Louis, reckoned annually since January 1, 1900, was about 73 per cent above the average percentage mortality during the previous five years.

2294 (Explains method employed in computing percentage of mortality from typhoid fever in St. Louis.)

2296 (Upon being examined as to the limit of 4,000 as a basis fore the estimate of urban population, witness stated as follows:) I have no doubt that on the Illinois, Mississippi and Missouri rivers there is a considerable number of people residing actually upon the banks and the water, engaged in fishing largely and sometimes in agricultural pursuits, and all of whose sewage goes directly and without any intermediation whatever, into the rivers. I have no doubt that among such people there is a considerable amount of typhoid fever.

2297 The percentage of typhoid fever deaths in the assumed river population would be somewhat larger than the same per cent of the assumed urban population having the same water supply. In my testimony I did not calculate any percentages on the urban population. What I did say was that the addition of Chicago to the urban population upon the river above St. Louis was an addition of about 63 per cent.

2298 In making these figures, I took the census as I found it. I do not know whether in the census they counted this river population that is floating about.

2299 The rural population, so-called, contributes very largely to the pollution of streams in whose watersheds they reside, using that word as distinct from infection.

2300 As to the method of disposing of sewage in communities having a population of less than 4,000, spoken of by me in my direct examination, I do not know whether that process prevails in the villages and towns along the Illinois, Mississippi and Missouri rivers, having a population of less than 4,000 inhabitants. It is a fact in sanitary science that the pollution of rivers by what we term the rural population is a very large factor in the consideration of the amount, and degree and kind of pollution, but scientifically, considering infections I do not take it so much into account, because in a rural population infection, to begin with, is less common. In the second place, owing to the time factor which is apt to come in, in the partial purifi-

cation of pollutions, the infectious materials may be destroyed. I have no knowledge as to whether the mortality percentage along the Illinois river is greatest in the urban or in the rural population. Take a common rural population—meaning by that a population not in a village or city of 4,000 inhabitants or more, such a population enters very largely into the consideration of all sanitary questions in regard to the pollution of rivers and into the consideration of the infection of rivers. I think I have the means of determining what per cent the rural population of the Illinois river watershed adds to the population of the watershed of the Mississippi river. I don't know that I can lay my hands on it at this moment but I think the data for such a comparison exists.

2302 I have not in my mind approximately what that per cent is. I have very definite ideas of the time in which the typhoid bacilli do actually live in the waters of running streams. I think I have traced the typhoid bacillus by its effects from the place and time of its origin until it ceased to exist in any given case. I might refer to the Newburyport case.

Q. What was your evidence in the Newburyport case?

A. My evidence was of this character, I traced a small epidemic in Newburyport to a larger epidemic in Lowell, and I knew by the history of the disease in Lowell and in Newburyport, when I had a right to assume that the germs in the flowing water had gone by. Still, I must confess, I do not know how long they remained in the sediment of the river, if any were deposited.

2303 There was reason to believe that it was constantly more or less infected from the sewage of Lowell. The distance is about 30 miles from Lowell to Newburyport. The Merrimac in places is a rapid stream. There is one dam between Lowell and Lawrence and the stream is a tidal stream at Newburyport but not at Lowell.

2304 I should not say that it took the typhoid bacilli injected into the river from the sewers of Lowell more than two

or three days to reach the intake at Newburyport. I should say not less than three probably and should not suppose it would be more than five or six but I really do not know. In my direct examination, I stated that at Lawrence, the germs came down nine miles and were pumped presumably into the service reservoir of Lawrence and by comparing the time elapsing between the corresponding periods of the two epidemics in Lowell and Lawrence, and knowing the custom of the water department of holding the water in the reservoir, I have estimated that the bacilli may have lived in the water for between one and three weeks, covering a distance of perhaps ten miles.

2307 If any one maliciously threw typhoid fever germs into the stream with the expectation that they would kill people below, and if they did kill people below, I should convict him of murder.

Q. That is, if the particular typhoid fever germ which he threw into the river were shown by the evidence beyond a reasonable doubt to have produced it?

A. If the evidence was conclusive, that is the act had produced the death of innocent persons, if the act was knowing and intelligent, and if he knew that his act was of such a character as would be likely to produce the deaths of such persons, and if he were sane, I should. In this particular case, I should not expect to detect the germs. Theoretically, I know that the bacilli that killed this suppositious man, he might have received from any other of a dozen different sources.

2308 I hold in a case of this kind, it is not necessary to discover the bacillus. It is sufficient to get the facts of epidemic and connect them as is done constantly in sanitary science, and I think might be applied legally in a case of this kind. My first step would be to exclude every reasonable possibility from my mind as to the derivation of the death-dealing bacillus from some other source. I should also consider that there was no isolated case, any infection from washing infected hands in the river and any other of a thousand ways in which the bacilli might be put in the river.

2309 I want to give you the exact dates in the Newburyport case. The supposed causative cases appeared in Lowell in December, 1902, and reached Lawrence and Newburyport in January, 1903. From my own personal experience, I do not know of a case of typhoid fever which was certainly traceable to typhoid bacilli which had existed for any length of time in the sediment of a running stream. My opinion as to whether typhoid bacilli do exist in the sediment of running streams is derived partly from my reading and partly from my general biological and bacteriological acquaintance with the typhoid bacillus and with bacteria in general.

2310 I do not think it is stated in the reports whether in the Zurich instance, the bacillus of typhoid fever was actually discovered in the sediment which was disturbed at Zurich. I think I have read of some cases in which it was believed that the typhoid bacillus had been discovered in sediments of a running stream. I do not remember now, in what book, and I am not even sure that such was the case. Other bacilli have been discovered in great numbers in the sediments of running streams very frequently and with great ease.

Q. And because other bacilli do live, you reason that the typhoid bacilli may live, or do live in the sediments of running streams?

A. I reason partly by analogy; partly from the general behavior of bacteria in organic materials, and partly from the epidemiological evidence that I have referred to. We have a great deal of evidence outside of the Zurich and Detroit cases. The fact that the beginnings of freshets are very apt to cause epidemics of typhoid fever in communities using the water derived from such freshets, indicates very clearly that heaps of material at the mouths of rivers or in running streams when stirred up may and do cause epidemics of typhoid fever. It is a well known fact that washing in of materials from banks of streams has, as I understand, produced some of our worst epidemics. I should attribute epidemics in an uncertain proportion to both surface washings and sediment washing in case of freshets.

2312 I do not recall any cases in which the bacteria of typhoid fever has been discovered and identified in the sediment of running streams. First experiments in laboratories showed a short longevity for typhoid bacillus but as time has gone on the opinion has I think grown among the bacteriologists —it certainly has in my mind—that those earlier experiments upon the germs were based upon unnatural conditions and that under perhaps slightly different conditions, in mud or manure, the typhoid germ must live very much longer than we had at first believed.

2313 Bacteriologists differ among themselves, like other men. They are at war among themselves as much as doctors, more or less. I don't know that I ever heard any bacteriologist say that the typhoid bacillus would live in a journey of 400 miles in running water, nor 300 miles, because such assertions would be fool assertions.

2314 He doesn't know whether they would live in such a journey or not unless he knows more about the conditions. I have said over and over again that it is not so much the distance, it is the time that comes in and bacteriologists don't go around making assertions of that sort—at least, the good ones don't. I am ready to assert my positive conviction that typhoid bacillus may and do live to make the journey from the Drainage canal through the Illinois river down the Mississippi, to the intake tower at St. Louis.

Q. Based on what evidence?

A. Based on the whole chain of evidence which I have in my possession regarding the sanitary history of Chicago, the character of the water used to dilute the sewage of the city of Chicago, the character of the Illinois river, especially as to being subject to floods, and the character of the Mississippi river into which the Illinois empties, and with which in my opinion, the Illinois freely mixes, so that such germs may be carried alive and virulent, from the people of Chicago to the intake tower of the St. Louis waterworks, and further, upon the vital statistics

of the city of St. Louis, as I have studied and compared them with the vital statistics of other communities.

2315 I think I may say it is an extension of the theories as to the existence and time of existence of typhoid germs in running streams but I am not ready to say that it is a very large or remarkable extension, all things taken into consideration. I should say the same thing if an identified body of sewage or water, took five weeks to make the journey or five months. If the time required were one year, I should want to know a good deal about the sediment and the particular conditions that prevailed during that year. I can conceive of conditions which might destroy the germ en route during that time or even before that time, but I can as readily conceive of other conditions which might prolong its life—for exampie, the pouring of a large quantity of acid from manufacturing wastes down the canal during that year might conceivably destroy the typhoid germs in the water and in the sediment. On the other hand, the pouring down of an unusual amount of organic matters from the stock yards, or from some other place, might so enrich the water as to sustain the life of the germs, perhaps even leading to a greater duration of life than that that you have stated. The fact is that the conditions which have got to be considered in a case of this kind are so many that it is impossible to make categorical answers which will have any real value, unless all of the conditions can be assumed, and that is impossible.

2316 If the journey took one year I think the chances are good that for the greater part, the germs have died out, but I should be afraid that some might still be alive, if they came in Chicago sewage, in conditions existing in the Illinois river -I should expect that some might still be alive—a small percentage. I should say that in regard to the periods beyond a few weeks or months that in general the mortality among the typhoid bacteria would be heavy but that I should never feel certain personally, even after one or two years, or possibly longer, that some of those were not still alive there. I, as a biologist and sanitarian, can see no reason why these little fellows may not, under some

circumstances, have their lives very extensively prolonged, and at the present state of our knowledge—indefinitely prolonged. Of course, I mean in diminishing numbers and with a small percentage left.

2317 I think we may fairly assume that there is a diminishing virulence, but there again we are very much in the dark, as we are in a good many of the finer points in bacteriology and medicine. The best place for the typhoid bacilli to thrive and multiply is in the human body. They thrive also in our laboratories under favorable conditions for that purpose. Nothing is known as to their multiplying in nature outside of laboratories. The general acceptation of the most modern bacteriologists is that they do not multiply in running streams. It is commonly supposed that Asiatic cholera lives in the polluted water butts of Calcutta the year around and I think the same thing was found, or believed to be found in Egypt.

2318 Am fairly familiar with the bacillus prodigiosus. There are what some bacteriologists believe to be varieties, and others hold them to be distinct species. On the whole, I believe it is a very well defined species, with no troublesome varieties turning up.

2319 Do not know whether it exists in the waters of the St. Lawrence river, Lake Erie, Columbia river, Lake Michigan or Missouri river. In other words, I may say I do not know whether it exists, but that in my experience, it is not found ordinarily, so that while I don't know whether it exists in those places or not, I should be very much surprised to find that it did exist there, unless exceptionally and rarely. (Same answer applies to the Mississippi and Illinois rivers.) I have never found it in natural waters of the United States.

2323 If numbers of bacillus prodigiosus—large numbers—were injected in a stream and the numbers were large enough to stock the stream pretty well, it would not be very surprising if they were taken up the stream by boats, for instance in the process of washing the decks of the boats, by pumping water from the river. If they were in any water that

was conveyed up the river, I should expect them to come with it.

2324 My opinion is that if the waters and sewage coming from the Drainage canal should be wholly diverted into another channel so that none of such waters could enter into the Mississippi river or into the intake of the St. Louis waterworks, and that the only waters that could enter such intake would come from the Missouri, Mississippi and Illinois rivers—excluding the water and sewage from said Drainage canal, that such waters would not be suitable and safe for drinking purposes, in their natural state, or as they enter the intake tower of the St. Louis waterworks.

2325 In my judgment it is entirely possible and practicable to so treat the waters which now enter the intake of the St. Louis waterworks that they shall be suitable and safe for drinking purposes on the part of the citizens of St. Louis. I have taken pains to satisfy myself that the present system of supplying water to St. Louis is now substantially the same as it was prior to January 17, 1900. In my judgment it is now and was, prior to January 1, 1900, insufficient for adequate purification.

CROSS-EXAMINATION by Mr. Todd:

The death rate of typhoid fever is taken as a basis of calculation in preference to taking the number of typhoid cases, as a matter of taste largely.

2326 Investigations have been made and results obtained by various observers and the general result is that the number of microbes discharged in a day from a normal human being is very large—enormous—and that in cases of typhoid fever, the probable discharge is also very large.

2327 By a normal typhoid death rate I mean a death rate which places a city or town having it, in the ranks of cities and towns having good water supplies and good general sanitary arrangements and conditions. This is the sense in which I used the expression that the rate of mortality in the city of St. Louis was normal. If there were 215 deaths and 788

cases in 1893 that would not be a normal number of cases, it would be too small. That means that the physicians did not report the cases.

2327 If it should appear that in 1899 there were 130 deaths and 908 cases of typhoid, that would come near being normal, but here again the number of cases is rather small for the number of deaths. The normal death rate from a sanitary standpoint for typhoid in a city with the population of St. Louis, would be about that which St. Louis had in 1895 to 1899 inclusive, although it might be lower than that under the most favorable circumstances. I attribute the presence of typhoid in St. Louis from 1895 to 1900 to a variety of causes. For example I have no doubt that the water may have contributed something to the net result. Milk, oysters, secondary infection,

2328 dirty hands and that sort of things, from person to person, and also infected foods other than milk and oysters, such as watercress, celery and unwashed fruits, flies and animals and other factors.

2329 I cannot give you the name of any French or English bacteriologist who has discovered the germ of typhoid in an oyster.

2333 I must frankly say that I believe a part of the rise in typhoid cases in 1900 was due to the same cause which operated at the end of 1899. The amount of typhoid fever in St. Louis at the end of 1899, in a city of this size and considering the season of the year, is entitled to be called an epidemic, but it was somewhat above the ordinary.

2334 I should consider an increase such as I have actually found in typhoid in St. Louis for the period since the Drainage canal was opened, 73 per cent, a large increase. (See record 2335.)

Q. If the number of deaths in 1890 was 277, to what would you attribute this high death rate?

A. I don't believe I should be able to answer that question. I would have to give it up.

2341 Typhoid fever may be conveyed by small particles of

sputum from the patient, flying off in the air and by kissing. There are at least two or three thousand wells in St. Louis. I have no doubt that some of them are located in the neighborhood of out-houses. I exclude altogether the
2342 wells of St. Louis as producing any important part of the increase of typhoid fever since January 1, 1900. (For reasons, see record 2342 and 2344.)

2343 Q. How many wells in the city of St. Louis have you investigated personally, that privies drain into? A. None.

Q. How many privies in the neighborhood of those wells, within these three years, have received the excreta of typhoid patients?

A. I don't know..

Q. How many people living in the houses where these wells are located and drinking the well water, have contracted typhoid fever from them, if you know?

A. I have no means of knowing.

Q. And in the absence of knowledge upon those three propositions, do you claim as an expert sanitarian, that your conclusions in answer to my former question were established beyond a reasonable doubt? A. I do.

2344 MR. TODD: If conditions existed in any of the wells of St. Louis where fissures appeared, permitting the contamination of privies to enter the wells, such as you have indicated in part of your answer, have you investigated to ascertain whether that condition obtains or not?

2345 A. I have not. If that condition should obtain, then in my opinion, it would be a serious menace to the health of the people drinking that water. I do not know whether in the three thousand wells in St. Louis, that condition obtains in one or more wells.

2346 I do admit that conditions may exist whereby the water of a well may be contaminated as well as infected.

2351 Q. Assuming that in the different sanitary districts in the city of St. Louis, where the typhoid was high in comparison with the other districts, that there existed a num-

ber of infected wells, would not that condition account for the typhoid in St. Louis for 1900, 1901 and 1902?

A. It might, if one were justified in making such an assumption and excluding from the same assumption the possibility of the occurrence of infected wells in other districts. (See pages 2350 and 51 for the number of wells and number of deaths from typhoid in 1900, '01, '02, in the seven sanitary districts composing the city of St. Louis.

2357 (Witness is asked question giving the number of deaths for 1900, '01, '02, in Lincoln, Kansas City, Quincy, Des Moines and Indianapolis from typhoid fever, and stating that those deaths indicate a gradual rise from 1900 to 1902, and asking the witness as to the cause of this apparent increase.)

2358 Objection by Mr. Jeffries and General Crow.

A. Having made no investigations of the sanitary conditions and causes of the typhoid fever in any of the cities mentioned, I am unable to give any reasons for the facts stated. In the case of Kansas City, it is apparently not very large and may be due simply to the rapid increase in population.

2359 MR. TODD: Professor, in the hypothetical question put to you by Mr. Jeffries, and the tabulation of typhoids from each of the cities located on the water-shed of the Missouri, Mississippi and Illinois river, exclusive of the sanitary district of Chicago, would you regard the excreta of the typhoids that appeared in each one of those several cities, if emptied into the rivers, upon which those cities are located, alone sufficient to make unsafe the water supply of St. Louis? By that I mean any one city, as distinct from all the cities?

A. I should certainly regard the rapid and practically continuous pouring of typhoid excreta from such a number of cases as appears to have occurred in any of these cities, as contributing to make the water supply of the city of St. Louis unsafe, but inasmuch as this is purely a theoretical question, and as a matter of fact, such a condition does not, and in the nature of the case, cannot exist, and furthermore, keeping in mind

the partial purification of the water supply of St. Louis after it has been taken from the river at the Chain of Rocks, I cannot say whether I should or should not under real conditions, so regard the water.

2360 I have no doubt that the number of typhoid fever deaths and cases existing during the three years mentioned, 1897, '98, '99, upon the watershed above the intake of the St. Louis waterworks, which numbers would indicate perhaps between three and four thousand cases, annually, would render the water supply of the city of St. Louis, if taken at the Chain of Rocks and delivered to the citizens unpurified, somewhat unsafe and somewhat dangerous, but it must be borne in mind that many of these deaths occurred at very remote points. It must be remembered furthermore that at no one time was there anything like any such number of cases as three or four thousand, and that for some periods, the number of cases and deaths upon this immense watershed must have been comparatively very small, so that there may have easily been times during those years, or any one of them, when the water was neither unsafe nor dangerous. Putting all the facts together, then I should say that inasmuch as at no time was there any very large number of cases or deaths upon the said watershed, exclusive of the sanitary district of Chicago, so far as I am aware, and inasmuch further, as the water taken from the intake tower at the Chain of Rocks was considerably purified by sedimentation before its delivery to the people of the city, the danger at any one time could not have been very great. In point of fact, the statistics show that during those years typhoid fever in St. Louis was, for St. Louis, remarkably low, and the water probably better than for many years previous, excepting the years 1895 and 1896, when the conditions of the intake were similar to those which prevailed during the three years under consideration.

2361 I do hold that the pouring in of raw sewage materials into a drinking water stream is likely to render the water below unsafe for drinking purposes.

2363 There may be, however, times when such water could be used with safety owing to the so-called self-purification en route, by dilution, sedimentation and the time factor. Assuming the conditions to be as we have considered them, during the years 1897, '98, '99, I should not, as a sanitary engineer, be able to state the times when it would or would not be safe for the citizens of St. Louis to use the water that comes from the intake. I should probably not have recommended it for drinking purposes or as a safe drinking water at any time during that period, without treatment and purification, inasmuch as one would never know—assuming that typhoid bacilli once found access to the river above in these large numbers—with any precision or certainty, that these would have been effectually removed. I do not know whether the health department of St. Louis has ever examined any of the wells located in the city, but even if they had, I should not feel certain as to the results of such examination, because in the present state of the art, as I stated this morning, it is often impossible to tell by ordinary methods of examination whether a well is or is not safe for drinking purposes.

2364 If the excreta of typhoid fever should be placed in a privy vault, no man knows how long it would have to remain there before it would lose its infection. I believe it might be days, weeks or years.

2365 Ordinarily a privy vault does not closely resemble a septic tank, because it is a mass of tolerably solid material, while a septic tank is essentially standing or stagnant sewage. That is to say, something very much more dilute. At the same time, some privy vaults are undoubtedly septic tanks, but as to septic tanks, while I believe that pathogenic germs are relatively quickly destroyed, we are not yet in possession of sufficient evidence to enable us to speak with entire precision on that head. I do believe that under some circumstances the typhoid excreta in a septic privy vault might be disinfected and under slightly different conditions, might not; but the ordinary privy vault is not in my judgment, a

good septic tank. If the contents of such a vault should be placed where the same could get into a stream, it would contaminate the stream, both by way of pollution and infection.

2368 We attributed the cause of typhoid fever in Chicago in 1892, from the investigation I made, to the water supply.

2369 (Witness reads from his report of 1892.)

2370 The newspapers differed with us as to what was the cause of the polluted water supply at that time.

2371 If I remember right, they further quoted some of the city officials who made statements that the water supply of Chicago was pure and unadulterated. My paper was read before the American Statistical Association on January 22, 1892.

Q. Assuming that the water supply of Chicago was contaminated by the sewage emptying into the lake and this sewage was what caused the prevalence of typhoid fever in Chicago, would the elimination of all that sewage from Lake Michigan cause, in your judgment, a reduction of typhoid in the city of Chicago?

A. I should certainly expect it to do so. If the sewage of Chicago did not enter the lake, I should certainly not consider the lake water seriously contaminated water.

2372 In view of the fact that steamers are constantly passing in and out of the mouth of the Chicago river and that the lake apparently is used by numerous fishermen and pleasure seekers and that in times of extraordinary rain-fall the Chicago river may even today have its current reversed for a time, I cannot say that I should consider the water of Lake Michigan within four miles of the shore on the lake front of Chicago as a perfectly wholesome and suitable material for drinking purposes under the conditions assumed. I do not know of any large city in the country whose water supply rises to the perfect standard fixed by sanitarians.

Q. Do you know of any city in the country that will have a better water supply than the city of Chicago when the sew-

age of the Sanitary District is completely eliminated from Lake Michigan?

A. Yes, I think so. I think that the water supply of New York is better than that of Chicago would be under those circumstances, or would be likely to be later on. I think that the water supply of Boston is another example.

2373 If the sewage system of Chicago when completed will be a complete elimination of the sewage of Chicago from Lake Michigan into the Drainage canal, that ought to be followed by material reduction in the typhoid fever death rate. I should expect that it would be. As the reduction of typhoid takes place, the danger from the sewage of Chicago going into the lake will be thereby decreased. The elimination by that process will tend gradually to purify and improve the water conditions of Chicago so far as that element is concerned. That in turn will eliminate to a large extent, the infection of the Illinois river but if the rate fell off one-half and the total number of cases continued the same, owing to the growth of the city, or by any other means, then the quantity of typhoid material put in the sewage would remain the same.

2374 I assume that Chicago is going to be one of the greatest cities in the world, but I assume also that under the conditions mentioned, the typhoid fever death rate will fall off very largely. Yet, the total amount of typhoid material thrown into the Drainage canal may even get bigger than it is at present. As I recall the river when I examined it, I should say that some parts of the Chicago river at times were undoubtedly in such a condition as to be likely to abbreviate the life of pathogenic germs.

2377 Typhoid germs are found in various parts of the human body, especially in the spleen and alimentary canal. I believe that there are so-called cases of typhoid fever in the lower animals, but these are, to say the least, uncertain and I cannot say that the existence of such well-defined germs has ever been made out. We therefore look to the human subject as the source of pollutions of water, sewage and the like, rather

than to any of the lower animals. The sewage that enters the Illinois river at Peoria will purify itself within 25 or 50 miles, to a certain extent, but not to such an extent that I should consider the stream into which it is poured, fit for drinking purposes.

2378 In my direct examination I stated that if the water of Lake Michigan, considering the fact that the sewage from about a quarter of a million of people is discharged into the lake, was conducted through a conduit directly to Grafton, and that no other sewage from Chicago was conducted to Grafton, that such Lake Michigan water would be dangerous and unsafe to the citizens of St. Louis. I should say that the dilution would be enormous from Chicago; it would be enormous in Lake Michigan and would be still further increased in mixing with the Mississippi at Grafton.

2379 I am still of the opinion it would render the water supply of St. Louis dangerous and unsafe under the present conditions at the intake. As to whether it would be more dangerous than the water supply of St. Louis prior to the opening of the canal I cannot say. I have testified that I did not regard the Mississippi water, previous to the opening of the canal, as it arrived at the Chain of Rocks, as suitable for a modern city.

RE-DIRECT EXAMINATION by General Crow:

2381 During the years 1897, '08, '09, 1,001 deaths were reported on the watershed tributary to the intake tower of St. Louis. In Chicago during the same years, the total deaths reported were 1,115. The number of deaths reported on the watersheds tributary to the Missouri river for 1901 and 1902 were 1,144; for the same years in Chicago, 1,647.

2382 I do think there would be a material increase of cost in the proper management of filters at St. Louis by reason of the added pollution and infection from Chicago. This I state upon reflection, after having considered my testimony on cross-examination.

2383 The fact that Chicago had an epidemic in 1902 of typhoid fever and that such a thing is likely again to arise, the

operation of filters in the hands of any competent person would require extraordinary and constant attention and skill at St. Louis and such things are costly. The increase in population in Chicago to three or four million people might necessitate double filtration at St. Louis. (Witness refers to future consequences that might arise by virtue of the increased population in Chicago.) When we consider that during each of the three-year periods referred to heretofore, I have been able to learn of only about 11,000 cases of typhoid in the cities on the watershed on which the intake is located and that I find there must have been about 16,000 cases in Chicago during the period of three years since the opening of the canal, it appears that the opening of the canal has more than doubled the probable number of typhoid fever cases in the urban communities on the watershed above the intake. Although Chicago is 358 miles distant from St. Louis, some of the cities on the Missouri and Mississippi watersheds are even farther away. When I consider all these facts, I cannot escape the conclusion that the opening of the Drainage canal was a very grave addition to the sanitary and financial burdens of the people of Missouri using the water of the Mississippi below Grafton.

MR. TODD: I move to strike out the answer as not responsive and is not proper on re-direct examination.

In my cross-examination, reference has been made to the dams in the Illinois river; the general effect of dams is to hold back the water and produce slack water basins and any checking of the flow and slowing down of the stream—other things being equal, favors sedimentation and the disappearance from the supernatant waters of infectious material. The carrying down of the germs and the detention of them in the sediment removed them from the moving water in the first place, and in the second place, by detaining them, gives them an opportunity to die out more or less. On the other hand, streams are subject to scouring more or less frequently, and the disappearance of infectious materials is not necessarily their destruction. A con-

siderable increase in the flow of such a stream as the Illinois river must tend to favor the return to the supernatant stream or lake or pond of some of the materials which it had previously deposited.

2387 While there is undoubtedly a high value in sedimentation and storage of infectious materials and a tendency toward their permanent removal either mechanically or by death, I do not feel that the processes referred to are trustworthy means of sewage purification under such conditions as existed in the Illinois river.

2388 Although typhoid bacilli are very rarely found in running streams there are other bacilli that are transported by water and convey water-borne diseases and they are, for example, the cholera germ and the supposed germs of diarrhoea and dysentery. As to animals, while I do not know whether glanders has been found in water, still glanders is supposed to be conveyed from one horse to another by water. Anthrax has been supposed to be conveyed by water. There is every reason to suppose it might be so conveyed, because it is one of the hardest germs to kill, of all that we have. I dare say there is a record of anthrax being found in the Illinois by the State Board of Health, but I don't know.

2389 As it is so difficult to discover the typhoid bacilli in water, one must judge of their presence by the effects which the water produces on thos who use it.

2391 As to the typhoid fever at Pittsburg, I did not mean to state in my cross-examination that it was caused by the typhoid fever epidemic at Oil City or at Johnstown. The condition in Pittsburg was rather like that in St. Louis today—a large amount of typhoid fever, rather than what I should call an epidemic. It was not due to any special epidemic in Oil City or Johnstown or in any any other community upon the watershed, because I could not find in any of these, such unusual occurrence of typhoid fever, but rather that the regular and steady occurrence of typhoid fever in many places on the water-

shed had each contributed its proportional share to the making up of the total in Pittsburg.

2392 (Witness reads from his report in regard to Pittsburg.)

JUDGE JOHNS: I move to strike out the extract so read as irrelevant and incompetent.

2393 As I have already said, broadly speaking, people living on farms on a watershed, and away from the banks, generally take care of their wastes on their own farms.

2394 The fact that there were 19 deaths from typhoid fever in January, 1900, in St. Louis, which was a larger number than had happened in January for several years at least, in February, the number was 5, which was smaller than in 1897, 1898 or 1899, shows that the little outbreak at the end of 1899 (prior to opening of canal)—whatever it might have been due to, had spent itself, while the occurrence of 16 deaths in March, 1900, has been, I believe properly attributed by Dr. Ravold, to the opening of the Drainage canal on January 17, 1900. At least a part of that increase may have come and probably did come from that source. On the other hand, the deaths in the next month fell off again to four, which was lower than during the two previous years, so that it is not easy to be absolutely sure that the number 16 did really come to any great extent from the first arrival of the material held in the Drainage canal. I may add that it is only by taking these things in a large way and for considerable periods that any safe conclusion can, in my judgment, be drawn. Boardly speaking, I do not think that after sewage which is infected with bacilli of water-borne diseases, is placed in running water, there is any absolute safety in using that water for drinking purposes within a month's time.

2395 I have been looking over what I said this morning, or parts of it, and I find that in answering the next question to the last, I contradicted myself and I desire to put myself right on the matter. (This question and answer related to the cause of typhoid fever in St. Louis in 1900.)

2396 What I intended to say was this, that there is evidence

that the outbreak at the end of 1899 reached over into 1900, as is seen in the fact that there were 19 deaths in January in St. Louis, from typhoid fever, a larger number than had occurred in that month for several years previous. It is very clear that the outbreak referred to had spent itself in February, for the deaths in that month were lower than in any of the three years preceding. In March the number rises again to 16, being larger than for several years before in that month. It might be that some epidemiologists—in fact, I should myself have suspected, if I had no other explanation of the fact, that these 16 deaths meant a recrudesence of the previous outbreak. Fortunately, however, we have a simpler explanation in the fact that the Chicago Drainage canal was opened on January 17, 1900, and it is in evidence, I believe that not long after a mass of black and dirty water arrived at the intake of the St. Louis waterworks, which was believed to have come directly from the Chicago Drainage canal. In view of this evidence, I regard the excess in March, or at any rate, the larger part of it, as due not to a recrudesence of the outbreak at the end of 1899, but to the pollution of the St. Louis water supply by material arriving from Chicago. This conclusion was reached, I believe, or a similar conclusion by Dr. Ravold, who, as it seems to me, very properly attributed the greater part of the excess in this month to the cause described.

2397 (Objected to by Mr. Todd.)

In April on the other hand, the number was again low, which goes to show that the cause which operated, or the cause of the deaths in March, was apparently absent, or at least very slight. In matters of this kind, we must take the statistics in a broad way and cover considerable periods of time, if we wish to be absolutely sure. Mr. Johns in cross-examining me, stated as an assumed fact that the population along the banks of the Illinois river produced a larger number of typhoid cases than populations not upon the river.

2398 The increased flow from the Drainage canal would obviously move forward the typhoid dejecta from this pop-

ulation more rapidly and quicken somewhat its delivery into the Mississippi river and the time of its arrival at the intake. Judging chiefly by the typhoid fever death rate in St. Louis during the years 1895, '96, '97, '98, '99, the sanitary condition of the water supply as actually delivered to the citizens during those years, was good. Based on the typhoid death rate since January 1, 1900, and assuming that there has been no change in the treatment of the water supply of St. Louis, the death rate has been such as to place the said water supply under the gravest suspicion of contamination, to tend to remove it from the class of cities having good water supplies and to place it in or

2399 near the class having polluted water supplies.

RE-CROSS EXAMINATION by Judge Johns:

Since giving my answer to Mr. Hamlin stating that the expense of filtration of the waters of the St. Louis supply would probably be the same whether the waters of the Illinois River were added or not, I have been giving that question considerable thought. What I meant to convey was that in view of the infection that I believe comes from the Illinois iver, we should have to have here a more careful and expensive system than we would have had to have without it.

2400 Broadly speaking, I should say that for the last ten years the water supply of St. Louis ought to have been filtered. If they ought to have a filter, it ought to be managed with great care and by good men, in any event.

2401 Assuming that the waters of the Illinois River which entered the intake would be as one is to sixteen, I would not know what the additional expense would be in arder to filter this Illinois water.

2403 I don't think any one ever made a filter for non-pathogenic germs and I should not think it was necessary, broadly speaking, to make a differently constructed filter with reference to non-pathogenic than for pathogenic germs. If the Missouri River has twice as many germs in number as the Illinois River and the Mississippi River combined, at the intake, it would be necessary in filtering against the entrance of these

germs, to have very great care taken of the waters from the Missouri River.

2405 You have got to construct filters with reference to conditions.

Q. Well, the conditions being assumed that the Missouri River as to all kinds of bacteria combined and all kinds of solids in suspension and solids in solution, is much worse than the waters of the Mississippi and the Illinois arriving at the intake of the waters leading to the filter, it would be necessary in the preparation of that filter, to recognize the condition of the Missouri River, wouldn't it, and arrange to filter the waters of the Missouri, combined with the other two?

A. Certainly, if that were the fact and if that were the whole fact, but I don't understand that it is.

Q. I am assuming the questions and am responsible for them. If that were the fact then in constructing the filter you would construct it with reference to the very large predominance of the Missouri water requiring filtration, wouldn't you?

A. Certainly, if that were the fact and it was so all the time.

2406 Q. Suppose that a filter was constructed which would at all times and under all circumstances, filter successfully the waters of the Missouri river, wouldn't that filter at all times and under all circumstances filter with equal success, the waters of the Illinois?

A. I don't know. I should have to know more about the chemical composition of the waters of the two rivers, at different seasons and times. Not being sufficiently familiar with the general character of the waters to form an opinion, I should be unable to answer that question.

2409 I do not know whether or not the total increase in population of Chicago upon the basis of the census of 1890 and the census of 1900 is equal to, or greater than the total increase in population of all the other cities in the watershed of the three rivers combined, the Mississippi, Missouri and Illinois. I took into consideration, in stating the future pollution

of the Mississippi river, not only the increased population in Chicago, but the increased population in the watershed. I intended to include in my remarks the idea that if the population along the banks of the Mississippi should increase, as I anticipate, and excluding the population of Chicago and its consequent sewage, there might in the future come a time at very low water, when the Mississippi would be almost a river of dilute sewage.

2410 (The same applies to the Missouri river.)

Q. In which case, it would be necessary for St. Louis to get its water from the Merrimac, or resort to double filtration?

A. No man can say, but something would have to be done —something serious.

Q. Do you not anticipate that at some time in the future all these things will be changed, and these communities will destroy their sewage at their point of origin?

A. I have often wondered about that and tried to imagine what was likely to happen. As I think I intimated in some part of my testimony, that has been the general line of human progress in the most civilized communities. In England, for example, they are paying more and more attention to the purification of the sewage before they put it into streams, and similar processes are going on today in the older communities of this country. I was told that when the canal was opened in 1900 that the waters of the Illinois were very high and that there was an appearance of black water at the intake of the St. Louis waterworks.

2411 I understood that at that time the Missouri was low or at any rate, that the conditions were such that the mixed Illinois and Mississippi found ready access to the intake. I know that the pumps at Bridgeport undoubtedly at times did lift considerable sewage into the Illinois and Michigan canal, but I have always regarded the Bridgeport pumps as an uncertain element in the matter. I have understood the purpose of putting the pumps at Bridgeport was to pump the sewage of

Chicago into the Illinois and Michigan canal from substantially the same area as is now drained by the Sanitary canal. I have made no special study of the point, but I should judge there would be a difference of a day or two in the flow of the Illinois before 1900, in January, and after that time, with reference to the arrival of the waters at its mouth at Grafton.

2412 I should not expect that, assuming the quantities of sewage to be the same, that those two days more of time in arriving at the mouth of the river at Grafton would so immensely purify the water that it would be innocuous. Assuming that the dangerous qualities were equal in the two, I should not expect it to be so immensely purified in that lapse of two days as to remove 30 per cent of its dangerous qualities. I should not assume that it would remove 10 per cent of the danger, because any such assumption would be contrary to the facts. I don't think that a difference of two days would make any very great difference in the degree of purification under the conditions assumed, or existing, because the two days would be so small a portion of the whole period that if, for instance, the sewage came down in ten days, two days more would not make any difference—certainly would not make very much difference—in the life of the germs.

2413 Q. Which one of two individuals, one on the lake front in Chicago, and one on the Illinois river below Joliet, immediately casting dejecta, one into the waters of Lake Michigan and the other into the waters of the Illinois, would be most dangerous to the health of the city of St. Louis, if both were typhoid infected persons?

A. I think other things being equal, the one at Joliet.

2414 I am not prepared to say that the household sewage of the river population of the Illinois river is not as dangerous to the waters of the intake tower at St. Louis as the dejecta of the supposed 3,000 fisherman on the lake front in Chicago is to Chicago. I have never denied or failed to believe that there must be a lot of people along the shores of the Illinois river who throw things into the river.

2415 I should say that the three years after the opening of the canal show the greatest death rate from typhoid fever for the following reasons: (1) Assuming that the same amount of sewage from the same population was pumped in, in the old way, through the old Illinois and Michigan canal; it was really a very different sort of sewage. The conditions then existing on the Chicago river were totally different to those that exist today. At that time the Chicago river was a kind of sedimentation basin, and it not infrequently ran in the opposite direction to that which it now takes. It was for the most part a putrescent stream, resembling more or less what we sometimes call a septic tank. And also (2) because in certain places, owing to these facts, there were opportunities for the dying out of typhoid germs in that river or its branches, but thirdly, and perhaps chiefly, because the sediment deposited, as I have indicated, was from time to time belched out into the lake, as I have said, so that the Chicago water supply was often worse infected than it is today, indicating that the typhoid germs

2416 which now very likely come down to St. Louis, at that time, if alive, went on into the lake much more freely and more readily polluted the water supply of the city of Chicago. To sum up, because the conditions in the Chicago river were so different from those which exist there today, that it is not, in my judgement, difficult to explain the facts. I have, of course, thought a great deal about this question, and have endeavored to give it the fairest possible consideration. It is a perfectly natural question which you have asked me, and one that occurred to me long ago, and I have met it to my own satisfaction, studying all the conditions and remembering all the circumstances, and I may say that I believe that the period since the opening of the Drainage canal would be far more likely to be the one showing high typhoid fever in St. Louis largely because the typhoid germs formerly held back in the Chicago river, where they either died or were washed out into the lake by heavy rains from time to time, have since January 17, 1900, for the most part, been sent down the Illinois river, and al-

though many of them no doubt have disappeared en route, at least for the time being, they have in greater or smaller numbers, nevertheless, survived at other times, and even at some times have reached the intake tower of the St. Louis waterworks and caused typhoid in St. Louis.

2417 I don't know what the average rate of flow per mile of the waters in the Illinois and Michigan canal was for 15 years prior to 1900. I don't know what the average rate of flow of the waters of the Drainage canal has been since its opening.

GARDNER STEWART WILLIAMS examined in chief by Attorney General Crow:

2418 Am Consulting Water Supply and Hydraulic Engineer and Professor of Experimental Hydraulics in Cornell University. The results of some of my investigations which were presented to the American Society of Civil Engineers during the past two years recently received the Normal Medal, awarded by that Society. (States his experience.)

2420 Generally speaking, we have a practically equipped channel and streams of water at Cornell, with which hydraulic experiments are made. We are able to produce on the actual scale on which they exist, a very large number of the structures which are met with in the ordinary streams of the United States. The apparatus and streams which we have there are used both in connection with construction and in the line of original investigation.

2421 The water supply of Chicago, viewed from a sanitary standpoint is certainly the worst of any supply furnished to a large city on the great lakes; in fact I doubt if there is a supply of any of the smaller towns that has such a con-

2422 tinuous reputation for infection. The amount of human feces daily delivered into the sewers of Chicago is in the neighborhood of 4,400 cubic feet. That is, the solid human feces aside from any liquid mixture—that would amount to about 150 tons every 24 hours. It amounts to something more than 50 per cent of the suspended matter of Lockport, as appears from analyses there.

2423 The water used to dilute the sewage of Chicago as it is drawn through the Drainage canal is taken from Lake Michigan near the mouth of the Chicago river, and therefore, from immediately over those large beds of sewage deposits which have been found by investigators to be from one to four feet deep in some cases. Assuming then as I have stated, that the water supplied through the intake of the Chicago water-
2424 works is the principal cause, or one of the principal causes of the high typhoid death rate in Chicago, the water used to dilute the sewage of Chicago and sent into the canal would certainly be likely to carry typhoid infection into the Illinois river. Speaking generally, I should consider that the discharge of such an infected water as that which would flow into the conduits from Lake Michigan, near the mouth of the Chicago river, or along the lake front of Chicago into the Mississippi river would be likely to carry disease and infection into the Mississippi river at Grafton and would therefore be a menace to the health of people using the water of the Mississippi river below that point, for drinking purposes. Most emphatically, I do not consider the mixture of water and sewage discharged into the Des Plaines river at Lockport of such a character as to be safe for use for drinking purposes.

Q. How is the character of this liquid discharged into the Des Plaines river at Lockport, changed by the time it reaches Grafton on the Missisippi river?

A. It is changed by the dilution with the waters reaching the Des Plaines and the Illinois rivers from other sources, by the effects of sedimentation along the line of the stream and by the action of the vegetation along the same. There is no question that under the conditions which exist in those localities on the Illinois river near Joliet and Peoria, where slack water is found and where the current is low, there would be a very extensive deposit of the suspended material in the water upon the bottom of the stream, at such times as the flow through these portions is low and of a uniform character. As the pressure of the water varies from top to bottom, a particle in order to

settle to the bottom must be of sufficient weight to overcome the differences of pressure from layer to layer in the water.

2427 Consequently, the lighter particles in the water will be the last to be deposited and bacteria, which are of very nearly the same specific gravity as the water itself, will only be borne to the bottom when entangled with the heavier suspended matter which is finding its way to the bed of the stream. In other words, the mud will be deposited first and the lighter particles—the vegetable and animal particles later, if at all. Any condition which tended to change what is called the regimen of flow—that is, which causes a change in the velocities from the bottom to the top of the stream, will cause changes in the amount of deposition, and will also frequently lead to what is known as scouring. It is particularly likely to stir up the suspended matter in the layer of water next to the bottom which is in a very dry unstable condition, and to distribute that material which in the quiet portions of the stream would be largely made up of the vegetable and animal life in the water, back into the stream.

2429 It is not necessary to have a condition of flood waters to take up the suspended matter and move it down from behind a dam. A very small change in the stage of the river at low water time would make a very decided difference in the transportation of sedimentary matter.

2430 The passage of boats would have a very decided effect in stirring up the deposits along the bed of a stream. This was evidenced by our investigations in the St. Mary's river. The observations were made by means of current meters after a boat had passed.

2431 In times of flood, the particles of sedimentary deposits which would be first picked up would be those in the layers of water overlying the bed of the stream, or in other words, those that were last laid down.

2432 The lighter particles of the suspended matter in the water and the lighter particles of the matter lying act-

ually on the bed of the stream. Winds are very likely to cause similar disturbances. It has been observed on the great lakes, particularly Lake Erie, that after heavy winds, the waters of the lake are charged with greatly increased numbers of bacteria. At times of flood or of the disturbance of waters, I should say that the bacteria would be much more likely to be re-suspended, and when re-suspended would be carried much farther than would the particles of mineral matter. The bacteria thus stirred up would be carried on down stream. They might be in part re-deposited somewhere in the course of the flow, but some of them would undoubtedly be carried for very long distances in the water and in the case of the Illinois river would be discharged into the Mississippi. Whether the germs of typhoid coming from sewers of Chicago and passing by way of the Drainage canal into the Des Plaines and Illinois rivers that might be deposited in the bed of these streams and remain there for considerable periods, would be entirely destroyed or not, would depend upon the length of time which the bacteria might remain deposited in the bed of the stream, but under such conditions as existed upon the Des Plaines and Illinois rivers, receiving the sewage of the city of Chicago, I see no reason to believe that germs deposited in the bottom of the stream would be destroyed under existing circumstances.

2434 I have made an estimate of the length of time required for the passage of water, under existing conditions, from Bear Trap dam at Lockport, to the mouth of the Illinois river, and it appears that we may expect the water to travel this distance under the different conditions existing in the stream, in from one to three weeks, speaking generally. I estimate that in 1900, during something over 300 days, water would have flowed from the Bear Trap dam to the mouth of the Illinois river in less than 15 days. The discharge into the Missisippi river at Grafton, of the Illinois river, after the latter has received the mixture of Chicago sewage and water at Lockport, tends to increase the pollution and infection of the water of the Mississippi river

and render it less safe for use for drinking and general household purposes below the mouth of the Illinois. When the Mississippi is in flood and the flow of the Illinois not above normal, I consider it possible for the waters to become so mixed as to effect the quality of the water upon the Missouri shore of the Mississippi river.

2435 That brings us back to the question again of the distribution of velocities and the distribution of pressure * * * * we may perhaps place this in more popular language by saying that the swifter moving stream exerts a suction upon the water of the slower moving stream, which leads to the dissemination and mixing of the latter throughout the volume of the former. The mixture would occur to a more considerable extent when the Illinois river was in flood and the Mississippi low, by reason of the velocity of the Illinois river, the momentum of the particles delivered into the Mississippi would be such as to carry them well out into the stream. In fact, it is observed that when the Illinois river is in flood the waters do pass well out into the main stream of the Mississippi river. The backing up of the Mississippi water into the Illinois river would have the effect of producing a quite thorough mixture of the waters of the Illinois and so much of the Mississippi as backed up into the stream, and as the flow or effect of this water which had been stored in the Illinois, considering it as an estuary, as it came out of the Illinois, would have the same effect as a flood rising in the Illinois itself, and producing an effect of additional scour on the bottom of the stream, and carrying the water into the Mississippi, which then being flowing rapidly, would have the mixed water more generally disseminated throughout the main current than would be the case with the rising river. I am prepared to state positively that at times the waters of the Illinois river reach the intake of the St. Louis waterworks.

2437 Even supposing that all the disease germs and infectious matter in the diluted sewage of Chicago as it passes Lockport should be rendered inocuous, under such circum-

stances, I should consider that the discharge into the Illinois river of the quantity of water now delivered through the Drainage canal would be a menace to the health of the people of Missouri using the water for drinking purposes for the reason that this quantity of water added to the stream during the low water periods, tends to materially decrease the time required for the flow of the water from various points along the Illinois river where pollution and infection may be and are added to the stream and thereby increase the liability of such pollution and infection reaching the Mississippi river in condition to do injury and harm to the citizens of Missouri who may be using the water.

2438 Each year the water of the Chicago Drainage canal would probably arrive in the Mississippi river at the Chain of Rocks within ten days of the time that it passed over or through the Bear Trap dam.

In making this estimate I used the proper methods that are used by hydraulic engineers in estimating the flow of streams to the best of my ability. Considering the suspended matters in the diluted sewage at Lockport, the quantity of water flowing in the Drainage canal and in the Des Plaines, Illinois and Mississippi rivers, I find that during about seven months in the year, the dilution of the suspended matters in the diluted Chicago sewage delivered into the Des Plaines river at the Bear Trap dam, when the said sewage and water reach the Mississippi river at the Chain of Rocks, would be from one-half to one part per million and that in the case of very low water in the Mississippi, the dilution might be reduced so that the suspended matter would represent a dilution of only one and three-fourths parts per million.

2439 I mean that the ratio of the amount of suspended matter delivered into the Des Plaines river from the Chicago Drainage canal at Lockport, and the quantity of water flowing in the Mississippi river is as from five tenths to one part of the suspended matter, to one million parts of the water of the Mississippi river, and that in time of low water, this ratio may be

one and three-fourths parts of the suspended matter to one million parts of the water of the Mississippi river. This is based upon the solids which are in suspension in the sewage at the Bear Trap dam, and has no bearing upon any substances which may be in solution and therefore not appearing as solids in suspension, in the analyses of the water. At Detroit in 1892 a similarly diluted mixture of suspended solids from sewage matter produced typhoid fever. (Gives a description of the Detroit epidemic. See pages 2442-3 in regard to conditions existing on St. Clair river and Lake St. Clair, as to depth of water, rate of flow, etc.)

2443 I think that ten days is a fair estimate of the time required for the water to travel from the place where this material was dumped to the intake of the Detroit waterworks.

JUDGE JOHNS: I move to exclude that answer and to exclude all testimony descriptive of Lake St. Clair and its waters.

2444 The period of incubation for typhoid fever may be as short as seven days, or it may require in the neighborhood of four weeks, but probably about 75 per cent of the cases will incubate in from 10 to 15 days of the time infection is taken. I have concluded that 12 days is a reasonable and proper period of incubation to be allowed in the study of typhoid epidemics.

2445 I found that making allowances for the time required for infection to come from the point at Port Huron where this material was discharged into the St. Clair river and allowing the average period of incubation and the ordinary time to elapse between the taking down of the patient and the occurrence of death, that the sum of such times agreed within 24 hours with the time which had elapsed from the deposit of the dredged material from Black river into the St. Clair river.

MR. TODD: I move to strike out the answer because the witness has not shown that he is in possession of facts of personal knowledge sufficient to make the answer that he has made.

JUDGE JOHNS: I move to strike out all the witness' testimony as irrelevant and incompetent.

2445-6 (Witness makes comparison of Detroit waters with those of the Illinois river.)

2447 The presence of infectious matter in the water of the Detroit river was indicated by a largely increased prevalence of typhoid fever in all the towns along the St. Clair and Detroit rivers which had public water supplies taken from the Detroit and St. Clair rivers.

2448 I have figured the dilution of the matter taken from the Black river and find that it ranged from a ratio of 55 of a part of dredged material to 1,000,000 parts of water, to 1.1 of dredged material to 1,000,000 parts of water. The materials dredged were composed of deposits of silt and sediment apparently coming from the sewers of Port Huron. In ordinary stages, I would state the range of dilution of the sewage matter of Chicago, from the Sanitary District of Chicago, in the waters of the Mississippi river flowing past the Chain of Rocks to be from .5 of a part of suspended matter to 1. part of suspended matter in one million parts of water.

2450 Port Huron had sewers in 1892 and they discharged into the Black river. There had been typhoid fever in Port Huron during September and October, 1891. (Objection by Mr. Todd.)

2451 This dredging and dumping was done in the Black and St. Clair rivers in 1892. It began April 16, and the work continued on through the year, but the dredging of the particularly infectious matter ended in a comparatively short time—it was a matter of a few weeks.

2452 JUDGE JOHNS: I object on the part of the State of Illinois to all the testimony with reference to the history of the epidemic at Detroit, as irrelevant and incompetent.

2453 The quantity of the dredged material dumped daily into the St. Clair river at Port Huron in 1892 varies in amount from two to five times the amount of human fecal mat-

ter that is delivered by the sewers of Chicago into the Chicago river and thence into the Drainage canal each day. (Objection by Mr. Todd and Judge Johns.)

2454 Made a thorough investigation of conditions in Detroit and failed to find any local cause for this epidemic or any cause other than this dredging of Black river at Port Huron.

MR. TODD: I move to strike out the answer for the reasons heretofore stated. There has been considerable dredging in the Detroit, Black and St. Clair rivers and in Lake St. Clair since 1892. This has always been accompanied by increased typhoid fever in Detroit.

JUDGE JOHNS: In order to save the necessity of objections to each question and answer as propounded, the State of Illinois now objects to all testimony to be elicited from this witness with regard to investigations either by himself or other persons, of the cause of typhoid fever, and in any other place than in St. Louis, arising from infection of the waters at the intake at St. Louis, caused by the inflow of drainage from the Drainage canal in Chicago, and insists that such testimony is neither competent nor relevant and desires that this objection shall stand to all such testimony from this witness.

Another instance where the disturbance and discharge of sediment from sewers into a running stream has caused typhoid fever among the users of the water of such a stream is that of Grand Forks, North Dakota. The main sewer of Crookston, Minnesota, became damaged so that it failed to discharge the material delivered into it. Temporary repairs were made and a small connection was made around the break which carried off a portion of the liquid matter of the sewage and discharged it into the Red Lake river, which was the stream into which the sewage of Crookston was regularly discharged. In the fall of 1893 the sewer was repaired and on November 17, the sewerage system of Crookston was flushed of the accumulations which had gathered during the several months preceding. Sixty cases

of typhoid had existed in Crookston in October and November, 1893. At the time of the flushing of these sewers into Red Lake river the river was frozen over. Grand Forks, North Dakota, is about 60 miles by river below Crookston. In November, 1893, there were reported in Grand Forks two cases of typhoid fever and no deaths. In December following the flushing of the sewers at Crookston on November 17, there were reported 230 cases of typhoid and 4 deaths; in January 712 cases and 52 deaths; February, 231 cases and 27 deaths; March, 46 cases and 11 deaths; April, 26 cases and 2 deaths; May, 1 case and no death.

2457 MR. TODD: I move to strike out the answer for the reason that witness has not shown that he had personal knowledge of the facts concerning which he has testified. (Witness again compares condition in St. Clair river with that in the Mississippi and Illinois as to flow and mixing.)

2458 Lake St. Clair might be and has been regarded as an ideal settling basin. When the Detroit waterworks was located, a commission of engineers, members of the United States engineer corps pointed out that in Lake St. Clair, Detroit was provided with a vast sedimentation basin which would add materially to the purity of the water drawn from the river at the point where it was proposed to take it. That report was made about 1860 or 1870.

2459 I am entirely satisfied that some of the infection in the sewage matter dredged in the spring of 1892 from Port Huron had remained or lived in that material for three or four months at least. I think it entirely probable that much of it had lived a very much longer time. The typhoid germs delivered into the St. Clair river at Port Huron must have lived a sufficient length of time to have traveled to Detroit, to have passed through the distribution system of the city, and to have been delivered to the consumers, and such time could not, in my opinion, have been less than eight or nine days, and in a great many cases, must have been as much as 12 or 15 days, or more.

2460 Typhoid infection usually comes into the water of streams through the sewage discharged into those streams. As a general proposition I most emphatically do not consider it safe to permit the discharge of human sewage in the streams of water which may thereafter be used as a source of water supply.

2461 It is my opinion that taking the conditions which I have found along the Drainage canal and streams which unite the sewers of Chicago to the intake, that typhoid infection or typhoid germs have at times come from Chicago to the intake of the St. Louis waterworks, that they may and will continue at times to do so under conditions which exist and which may be expected to exist in the streams aforesaid. The best criterion of the sanitary quality of a water supply that is being used by a community for domestic purposes, is the presence or absence among the users of such supply, of water-borne diseases, of which in this country, typhoid fever is at present the most important. The number of cases and deaths from typhoid fever in a community, I should consider the most important evidence to be adduced as bearing upon the sanitary quality of the water supply.

2462 The evidence afforded by the typhoid fever statistics of St. Louis for the period from 1895 to 1899 inclusive, indicates that while the water supply of St. Louis at this time was not ideal, it nevertheless would compare favorably with that of a very large number of our American cities. Considering the typhoid statistics since the beginning of 1900, it appears that up to near the end of January the water supply of St. Louis during the year 1900 must have been about as good as formerly, but that about that time there appears to have been considerable infection of the supply which has continued to increase from time to time since, with the result that the typhoid statistics show the probable infection of the supply during the year 1902 to have been nearly twice as great as existed on the average from 1895 to 1899 inclusive, and that the rank of the water supply of St. Louis has materially dropped, judged by the

standard of sanitay purity. I have not found anything in the typhoid statistics for the cities on the Mississippi, Illinois and Missouri rivers outside of the sanitary district of Chicago that would account for this.

2463 Basing my opinion upon the facts brought to light in an extended examination of the conditions which seem to me likely to bear upon the question involved, it is my judgment that to the discharge of sewage by the sanitary district of Chicago into the Mississippi river, by means of the Chicago Drainage canal, the Des Plaines and the Illinois rivers, is attributable the major part of the increase in typhoid fever, revealed by the typhoid statistics of the city of St. Louis since the beginning of 1900, as compared with the period from 1895 to 1899 inclusive. The fact that the chemical analysis fails to show the presence of disease producing infection, is no evidence to an expert that such infection may not exist in the water in question.

2464 A chemical analysis is a valuable aid in that it may show the presence of substances which would be inimical to the health of persons using the water. If it fails to show anything of a deleterious character, it is not to be accepted as evidence of purity. If it does show the presence of substances which are recognized as connected with infectious material, then it is to be regarded as a valuable indication of the possibility of contamination.

2465 Chemical analysis made of the water of the River Dee in Scotland, were entirely unable to detect the presence of microbes, while in the bacterial analysis simultaneously made, the bacterial content of the water was shown to contain thousands of organisms in a cubic centimeter. Analyses of the water of the Detroit river were made by competent and experienced chemists in 1892, who were accustomed to making analyses of that water and they expressed themselves as entirely unable to detect in that water any indication of pol-

2466 lution. The water at Detroit at that time was clear.

2467 I consider that whenever chemical, [illegible]opical or bacterial analyses of the water indicates the presence therein of substances which are known to be related to infectious matter, then it is proper to give to the evidence of those analyses, great weight in estimating the quality of that water and the expert should not recommend such water for use, speaking generally, until he is satisfied that the source of such organisms or such constituents or impurities, is such as to be unlikely to affect the sanitary quality of the water. On the other hand, it is not necessary for the expert to depend, or to require either a chemical or microscopical or bacteriological analysis of water to determine its pollution, if it is possible for him to see polluting matter flowing into it. Assuming that the numbers of bacilli coli communis in the waters of the Illinois river at Grafton are at intervals no greater than the numbers contained in it before the opening of the canal, I most certainly do not consider for that reason that said water is at all times no more dangerous for drinking purposes than before the opening of the Drainage canal.

2468 The germs of diphtheria, tetanus and anthrax have considerable length of existence in water. There have already occurred in St. Louis, cases of anthrax, one of which has been traced apparently to the water supply and the germ of anthrax is reported to have been found in the waters of the Illinois river. Should anthrax be present among cattle which are daily slaughtered in the Chicago stock yards and from them be transmitted by the discharges from the nostrils, mouths or bowels of those cattle, into the sewers of Chicago, there would be no question that the germs of anthrax might easily find a lodging in the people of Missouri with extremely fatal results.

2469 Should the sewage of Chicago become infected with anthrax there would be great danger of the occurrence of an epidemic of anthrax not only among the human inhabitants of Missouri, but also among the lower animals using the water.

Glanders is also transmitted through water and the same would apply to that disease.

2470 MR. TODD: I want to object to the question as to form and to strike it out as being based upon information and hearsay evidence.

Hog cholera is the nearest prototype of typhoid fever that is known among the lower animals. The bacilli of hog cholera are conveyed by water in the same manner as the bacilli of typhoid fever and coli communis, the three germs being very closely related. There is no doubt in my mind but what the cholera bacilli of hogs might be transmitted through the canal and the water-ways connecting the Mississippi river below the mouth of the Illinois.

2471 There is no doubt in my mind but what mud, silt and sewage matter under existing conditions may be removed from the bed of the Illinois river, the Drainage canal and the Des Plaines river into the Mississippi river and there deposited to remain for a greater or less time upon the bed and sides of such river. The volume of water added to the Des Plaines and Illinois river by the opening of the Drainage canal would unquestionably increase the quantity of such material so delivered because it has greatly increased the velocity of flow and has therefore prevented to a considerable extent the deposit of material which otherwise would have found its place upon the bottom of the stream.

2472 In the event of an epidemic of Asiatic cholera in Chicago under the conditions now existing in the waters between Chicago and the Chain of Rocks, through which the sewage of Chicago now flows, there is not only a possibility but probability and almost a certainty that the germs of the disease would be communicated or transmitted to the water supply of the city of St. Louis and the consumers thereof.

2473 If, with the knowledge of the existence of the conditions at Chicago and along the Drainage canal and the Des Plaines river and the Mississippi river, that are now known to me to exist, an expert should state that it is impossible for infec-

tious matter discharged by the sewers of Chicago to reach the Missouri shore of the Mississippi river, and the intake of the St. Louis waterworks at the Chain of Rocks, and to be a source of danger to the citizens of Missouri, residing on the Missouri shore of the Mississippi river and using the water therefrom for drinking purposes below the mouth of the Illinois river, and the citizens of St. Louis using the water supply drawn through the intake at the Chain of Rocks, I should say that he had thereby shown such lack of knowledge of the history of water-borne diseases, and the life and phenomena connected with their transmission and infection, as well as of the laws of flow of water in open channels, as to totally disqualify him as
2474 an expert upon the sanitary value or quality of a public water supply.

MR. TODD: I move to strike out the answer.

Considering the existing conditions in Chicago and the Sanitary District, the Drainage canal, the Illinois, Mississippi and Missouri rivers, I would, as an expert on water supplies, beyond reasonable doubt attribute the principal portion of the increase of typhoid in St. Louis since Jan. 17, 1900, to the infected sewage of the Sanitary District of Chicago. The most common method of sewage becoming infected with typhoid bacilli is by the discharge into sewers of the dejecta of typhoid fever patients. The most dangerous source of danger-producing infection in public water supplies of towns and cities in this country is the sewage of large communities.

2475 I have not any experience which would cause me to believe that any stream can be absolutely relied upon at all times to remove disease bearing germs such as typhoid bacilli, which may have been placed therein. (Witness testifies as to the effect on future generations of the discharge of Chicago sewage into the Illinois river and states that the menace to the health of St. Louis arising therefrom, will be much more tremendous and impending than exists at the present time, grave though the present condition be.)

2478 Based upon my past experience and knowledge, I would say the city of Chicago is today contributing considerably more than half of the entire sewage pollution which reaches the streams upon the water-sheds tributary to the Mississippi river above the Chain of Rocks. Upon examination of the population of cities of 4,000 inhabitants or more, resident upon the water-shed of the Mississippi river and its tributaries above the Chain of Rocks, exclusive of those residing in the Sanitary District of Chicago, and a comparison with the population of the said Sanitary District, contributing its sewage of the Chicago Drainage canal, I find that when the said Chicago Drainage canal was opened in January, 1900, there was added to the population previously existing in cities of 4,000 inhabitants or more, upon the water-shed of the Mississippi river, above the Chain of Rocks, a number of urban inhabitants amounting to over sixty per cent of those already there, and a number of sewage contributing inhabitants sufficient to more than double the number previously existing.

2479 I stated in my examination yesterday that the flow of water in low water stages in the Missouri would lessen as the years increase. This I attribute to the increase of population and the denudation of the forest areas.

2480 The amount of sedimentary matter carried by the Missouri itself will be reduced by reason of the reduction in flow in its upper tributaries and consequently its effect in producing precipitation of the bacteria in the mixed water will be deceased in even greater proportion than the decrease of percentage of Missouri river water at the intake.

2481 There has been an epidemic of typhoid at Ithaca, New York. The population is between eleven and twelve thousand with probably three thousand students. About half the deaths occurred among students. The water supply is taken from four sources. Cornell university takes its supply from Fall Creek. The public supply is furnished by a corporation

known as the Ithaca Waterworks Company and obtained from two streams—Buttermilk creek and Six-mile creek.

2482 The epidemic broke out practically all over the town excepting upon the campus and in those portions where well water was used exclusively. An investigation revealed the fact that the epidemic was beyond question, primarily due to an infection of the water supply of either Buttermilk or Six-mile creek, or both. An examination of the specific cause of the outbreak showed that it was possible it might have come from several sources, but the most probable source of the bulk of the infection lay in the fecal discharges of a gang of workmen who were employed by one of the railroads in the construction of some culverts across one of the tributaries of Six-mile creek, some five or six miles above the intake of the waterworks.

2483 It is quite interesting in connection with this epidemic to see that there were continued re-infections of the water supply following successive freshets. I have investigated the water supply of Charlevoix, Michigan.

2485 During the warm season of 1897 the U. S. Revenue Cutter Rush, came into the harbor into Round Lake and anchored several hundred feet away from the intake of the waterworks, having on board a case of typhoid fever; the dejecta from the patient was discharged into the waters of Round Lake. Typhoid fever made its appearance in epidemic form in Charlevoix within two weeks of the appearance of the cutter.

2486 JUDGE JOHNS: I move to exclude the answer of the witness as to the disease in Ithaca and Charlevoix.

CROSS-EXAMINATION by Judge Johns:

2487 At the time of the epidemic of typhoid fever in 1892, I made no kind of investigation of it. I was not then practicing that branch of civil engineering which pertains to the erection of water supply systems. I began investigating it some time in the fall of 1895.

2489 In my investigation of the cause of that epidemic, I embraced territory for 100 miles up the Detroit river, Lake St. Clair, the St. Clair river and Lake Huron. I did not go

further because I regarded it as quite improbable that typhoid fever infection contributed by any of the communities tributary to the shores of Lake Huron above the mouth of the St.

2490 Clair river—those communities being in general small and very few and they not discharging sewage into the lake anyway—could possibly contribute a sufficient amount of contamination to mix itself with the water of such a body as Lake Huron and thereby produce any such serious infection as evidently had existed in the Detroit water supply at the time I had under consideration. When I commenced this investigation in 1895, so far as I recall, I had no knowledge of a case where the infection was attributed to a travel of more than thirty miles in a water supply.

2491 When I commenced the investigation in 1895 as to the cause of typhoid fever in Detroit in 1892, I think it may be considered that it was a new branch of water engineering and supplies, to me.

2492 The first I knew that the harbor of Port Huron had been dredged was at a meeting of the Detroit Engineering Society, held at the Hotel St. Clair in Detroit, sometime in 1896 or possibly 1897. I will correct my answer. It occurs to me that information did come to me in a letter from the city engineer of Port Huron a matter of a few weeks before the meeting of the Engineering Society. I am unable to state positively, but I think it was late in the fall, possibly in December, 1896. I ascertained the number of deaths from the mortuary records of the Detroit Board of Health. They were recorded consecutively as certificates were issued.

2493 All that I know positively as to the number of deaths in Detroit is from an inspection of the records and from the public reports of the local board of health and of the Michigan State Board of Health. I did not go to Port Huron in 1896 to investigate the dredging done there in 1891 and 1892. The records of deaths in Port Huron were obtained from the Michigan State Board of Health. They obtained them from the health

officer of Port Huron. I did not know whether the report was correct or not.

2494 I do not know from the records, of the existence of typhoid fever in Port Huron prior to November, 1891, with the exception of two cases, which I recollect. The two cases I remember, my impression is they were cases and not deaths. Port Huron in 1891 had a population of nine or ten thousand.

2495 The population of St. Clair County in which Port Huron is situated in 1890 was 51,000. My impression was that there was no other town except Port Huron in that county, having a population of 4,000 or over. The towns with a population over 4,000, above Port Huron on the eastern side of the southern peninsula of Michigan, on the borders of the lake, are Bay City, West Bay City and Alpena. Alpena is pretty well up.

2496 Bay City and West Bay City together would have a population of 40,000. These towns are situated about three miles above the mouth of the Saginaw, which drains into Saginaw Bay, which is an arm of Lake Huron. St. Clair is between Port Huron and Detroit, on the shores of Lake St. Clair, with a population of 2,500 or 2,800. Marine City is also situated there, with a population not quite so large and Algonac which is nothing more than a village.

2498 There are flats or marshes in St. Clair Lake on both sides of the lake. There is considerable fishing in the delta at the upper end of the lake. The flats of Lake St. Clair are the delta of the St. Clair river and there are a number of summer resorts and club houses there.

2499 There is a considerable number of people visiting there, hunting and fishing so that there is a considerable number of constantly changing population on the lake during the summer season and the dejecta of these people goes directly into the water.

2500 You would be in Lake St. Clair in going a mile above the Detroit waterworks. In fact, I think in going half a mile. You would travel across Lake St. Clair about 24 miles to get to

the St. Clair river and 30 miles by the St. Clair river to Port Huron. The St. Clair river is the outlet of Lake Huron, Lake Michigan, Lake Superior and all their bays and estuaries, on the travel of the water of these three lakes to the sea. At Port Huron the river is 1800 or perhaps 2000 feet wide in places. The St. Clair river is not subject to very great variations upon the six feet.

2501 I believe such variations as six feet have been recorded. These are not sudden and violent but very gradual. I am familiar with the data or measurements of discharge and velocity by which the cubic feet per second of the flow of the St. Clair river is ascertained. I obtained this data in conversations with men who were carrying on the work, who have been intimate acquaintances of mine for years, and an examination of the data of the discharges and the reading of their reports in their offices. The discharge varies from 180,000 to 200,000 cubic feet.

2502 If the discharge was 180,000 cubic feet per second, it would be over 15,000 million cubic feet for 24 hours. The discharge of the Mississippi river at St. Louis is between 180,000 to 200,000 cubic feet per second during the greater portion of the year. I obtained that from the reports of the Mississippi River Commission and of the United States Corps of Engineers.

2503 I found reports which indicated very much less amount at times and a very much greater amount at times. On August 5, 1881, the gauging of the Mississippi river at St. Louis shows 179,000 cubic feet per second.

2504 I do not find any for 1900. If there were any published I investigated them. I am not sure there were any as late as that. The same answer would apply to 1901. I am quite sure that I did not investigate any for 1902. I wish to correct my testimony and say that Port Huron had a population of about 18,000.

2505 I do not think I have sufficient familiarity with the city of Port Huron in 1890, 1891 or 1892, to make a guess as to the number of people whose sewage was discharged into the

sewers of Port Huron. As to the volume or amount of such discharge, I have no kind of an idea, excepting that there were such discharges. It would be fair to estimate that 5,000 people discharged their household sewage into the sewers of Port Huron in 1890 and 1891, that would be between six and seven thousand cubic feet a year of solid matter.

2506 That would be about 230 to 250 cubic yards, or less than one-half the amount that was usually dredged in a day during the dredging of the Black river in 1892—substantially in round numbers, 40 cubic yards in two months. In the month of April, 1892, there was about 5,300 cubic yards dredged out of the Black river. That would be substantially 10,600 yards in April and May. This memorandum from which I read these figures was made by me from figures of some United States officer.

2507 I made this memorandum may be as early as 1897. I should assume 15,000 cubic yards would be a correct statement of the case and that 40 cubic yards might possibly be a fair estimate of the amount of solids in the household sewage coming from the bodies of persons using the sewers of Port Huron. I estimate the fecal and urine discharges of the people of Chicago who use the sewers of Chicago, which flow

2508 into the Drainage canal for one year, to be about 60,000 cubic yards, that would be 10,000 cubic yards for two months.

Q. Well, then, such solid discharges into the sewers of Chicago from the bodies of the inhabitants, which sewers enter into the canal are not five times as much as the entire amount dredged at Port Huron?

A. No, sir; they are not.

2509 The cubic feet of flow in the St. Clair and Mississippi rivers, assuming 180,000 cubic feet per second, would be 15,552 millions per day; for sixty days, being April and May, 1892, would be 933,120,000,000. In order to regularly, systematically and scientifically pollute a body of water flowing past Port Huron in the St. Clair river for one day of 24 hours, there

would have to be 15,552 cubic feet of polluted matter to make one part in a million of pollution.

2510 If 15,000 cubic yards were regularly and systematically in a constant and regular flow put into the waters of the St. Clair river at Port Huron, such discharge would not pollute the water of the St. Clair river for more than 27 days, that is, at the rate of one part per million.

Q. What per cent of pollution of 933,120,000,000 cubic feet of water is 40 cubic yards of solid material, stated in parts per million?

A. About 108-10,000.

Q. 108-10,000 of one per cent?

A. 108-10,000 of one part per million.

Q. Do you want to be understood as saying on the basis of these figures, that if there was the dejecta of two typhoid patients put in some time about the first of April, 1892, in 40 cubic yards of solid sewage, from the bodies of people, in 933,122,000,000 cubic feet of water which would travel 57 miles, that that dejecta would pollute the entire body of water during any considerable portion of that time, or any portion of it?

2511 A. Considering the fact that the number of bacteria found in the excrement of typhoid patients has been on the average about 200,000 million per day, and that if these patients were sick with typhoid fever and recovered, they would each have been discharging that excrement so charged with infection, for a period of sixty days, and considering that there were assumed to be two patients, we find that there would have been probably discharged into the sewers of Port Huron, and from there possibly into Black river, and the material dredged therefrom, 24 million million bacteria, which would have been sufficient to have put about 27 bacteria into every cubic foot of water discharged under the conditions assumed, and it therefore seems to me possible that the infection might have been so distributed. During March, April and May in 1892, figuring on seven and a half gallons to a cubic foot, there were on an average 4,500,000 cubic feet of water pumped into the Detroit water-

works daily; assuming that the water in the St. Clair river passing Port Huron in a day was 15,552 millions, the per cent of it pumped into the Detroit waterworks would be three-hundredths of one per cent I think. 27 typhoid bacilli to a cubic foot of water would be about 4 individual, separated bacteria roughly speaking, to a gallon.

2512 I see no reason why some of these four bacteria in a gallon of water traveling 57 miles might not live and be virulent. In a laboratory experiment in 1888 it was shown that in ordinary potable waters the germs had been found alive after two weeks and it would not take them two weeks to go from Port Huron to Detroit under the circumstances assumed.

2513 I do not know whether these two people died of typhoid fever in Port Huron. I do not know whether these two cases recovered, nor whether the discharges from their bodies were cast into the sewers of Port Huron nor whether such discharges were destroyed or disinfected.

2514 Q. Without stating what you may have in your mind, do you wish to be understood as a sanitary expert, epidemiologist and sanitary engineer, that under the facts and figures elicited by your cross-examination, you are still of the opinion that typhoid fever resulted from the dredging of the harbor of Port Huron, and the mouth of the Black river in 1892?

A. I wish to be understood as saying that it is my belief that the typhoid fever in 1892 was very largely caused by the dredging of Black river in Port Huron during the same year.

2515 Assuming that 5,000 cubic feet of human discharges are put in the Drainage canal in Chicago in one month, there diluted with 300,000 cubic feet of water per minute, as it continuously flows into the Sanitary canal and then travels 357 miles down the Illinois and Mississippi rivers to the intake, and by the time it arrived at the intake was thoroughly mixed with the Mississippi river water, arriving continuously during the month and being diluted so that during the month it was contained in 933,120,000,000 cubic feet of water during the same

month, understanding the word "pollute" to mean the addition to water of filth or infectious matter, or both, whether in large or small degree—I think that that sewage would pollute the intake waters at St. Louis.

2516 Considering the same facts and assuming that in this sewage there was dejecta from 75 persons who died of typhoid fever during that month, I wish to be understood that to whatever extent they might arrive at the intake, those bacilli in that dejecta would have a poisonous or deleterious effect on the waters of the intake, and I want to be understood as saying that they might arrive. I base that conclusion upon my knowledge of the life of the typhoid germ in water as determined experimentally; upon my knowledge of its transmission in the epidemic of Detroit, and epidemics other than Detroit; upon my knowledge of the conditions affecting the water supply of St. Louis previous to the opening of the Chicago Drainage canal; upon my knowledge of the conditions existing in and about St. Louis since the opening of the said Drainage canal, and the conditions existing in and about Chicago since the opening of the said Drainage canal, whence it appears clearly to my mind that there has as yet been found no other explanation sufficient to account for the increase now amounting to about 100 per cent in

2517 the number of annual typhoid deaths in the city of St. Louis, as compared with the annual number recorded during the five years previous to the opening of the Drainage canal, other than that the said infection has been received from Chicago throughout the Drainage canal, the Illinois river and the Mississippi river, and that therefore if much may come, it must necessarily follow that little may also come. I got my information about Crookston, Minnesota in the Engineering News and I believe it is also referred to in one of the health reports of Dakota.

2518 The report of this epidemic came to my attention along somewhere about 1897 or 1898. It was published in the Engineering News in 1893 or 1894. The author of the publica-

tion in the Engineering News was the city engineer of Grand Forks.

2519 There had been typhoid fever in Crookston. The supposition is that is where the typhoid epidemic of which we are talking, originated. I do not know how many cases occurred in one month, nor how many deaths there were from those sixty cases. I don't recollect whether I have seen a statement of the population of Crookston at the time the sewer became broken or clogged. I don't know what proportion of the people of Crookston have their household sewage emptied in the sewers nor whether any one of the supposed sixty cases had their dejecta thrown into the river. It was stated in the report that the city had sewers. Red Lake river at low water stage, its discharge has been shown to be 988 cubic feet per second. Grand Forks is 60 miles from Crookston. I do not know whether there were any cases of typhoid in Crookston prior to 1893 or 1892. I do not know whether there were any cases of typhoid fever there in January, February, March, April, May, June, July or August. I have no idea where the contagion came from that caused the supposed cases at Crookston or whether that was a water-

2521 borne infection or not. I should not wish to make the assumption that the infection which caused the disease in Crookston was water-borne, without further knowledge of the conditions existing there.

2526 I know that typhoid fever had been practically unknown in Charlevoix up to the time the United States Revenue Cutter came into the harbor. As to whether there had been or not, as a matter of fact I am not able to state positively. That boat remained in the harbor two or three days.

2527 The boat was in Round Lake and there was only a single case of typhoid on the boat. I have never heard whether or not the excretions of this typhoid patient were destroyed on board the boat or disinfected.

2528 Not knowing the usage on board U. S. boats in regard to the dejecta of people having contagious or infectious diseases, I presumed for the purpose of the investigation, that the United States officer allowed that stuff to be cast into the water.

2531 If 15,552,000,000 cubic feet each 24 hours passes into Lake St. Clair, as much water must go out through the Detroit river in order to maintain the stage of the water. It goes through with a velocity that I don't know that you would be warranted in saying that it was what would be dignified as a current.

2533 It would take a few hours for a body of water to flow from the head of the river at Detroit to the Detroit waterworks intake.

2534 I have not been up the Illinois river at a time of ordinary stage of water, nor at any stage of the water. I believe there are five dams in the river, but I never saw those dams in any stage of the river.

2535 Basins are created by those dams to a considerable extent. If a given dam on the Illinois river had a perpendicular heighth of eight feet above the pool below, in extreme low water it would back the water up the river a considerable distance. I am not certain that I have any information as to the fall of the Illinois river from Ottawa to Lacon. From Morris to Peoria the fall is 50 or 60 feet. From Peoria to Copperas creek dam, between 2 and 4 feet. The distance is about 30 miles. That is a very low grade. At certain stages that entire reach of river would be almost a sedimentation tank.

2536 I should say that at a stage of the river when the distance from the crest of Copperas creek dam to the surface of the pool below is six feet, the effect of Copperas creek dam would be to retard the flow of water above Peoria.

2537 When a dam ceases to be a submerged weir and is actually an effectual instrument in retarding the flow of the water above it, it does not necessarily aid in sedimentation and very frequently does not. The disturbance set up by the obstruction

by the dam when the water runs over the dam, in causing change of direction in the flow of the current, stirs up particles on the bottom and tends to carry them over the dam.

2538 If the dam was 7 feet high, I would be willing to say it might extend back 50 feet. The passage of a stern-wheel steamer up the Illinois and the consequent agitation of the water would not contribute to the purification of that stream. Bacterial examinations for instance of the Niagara river above and below the falls have shown no change in the bacterial contents of the water at all and I doubt if any stirring up by boats would accomplish anywhere near the result that the flow over the falls and the stirring up afterwards would produce. I am unable to say if the waters of the Illinois river were continuously agitated for thirteen days that it would add to the purification of the water. My opinion of the value of aeration is that it has been greatly over-estimated. I have no definite idea as to the length that the typhoid bacillus might live in the sedimentation of the Illinois river.

2539 I am quite sure it would live more than 15 days. I am unable to cite a case of specific experiment and at the present moment do not recall one as to the length of time that any given lot of bacilli lived in sedimentation. (Witness states on what he bases his conclusion that the flow of water from Bear Trap dam to Grafton occurs in 15 days, for 300 days of the year.)

2543 At an average stage it would take the water a little less than twice as long; sometimes less than twice as long, to travel over the distance as it would in the case of flood, so that if floats were run over the Bear Trap dam to Grafton in the Illinois river at a stage of high water in 10½ days, I should say it would take possibly, 16, 17 or 18 days in traveling the same distance. I think an addition of 6 or 7 days in the flow of a stream like the Illinois would be a considerable time factor in its purification.

2544 There are cases on record where a bacteriological examination has determined whether the water was infected or

not. There are some reported on page 93, paragraph 18 of the report of the sanitary investigation of the Illinois river and its tributaries, prior to and after the opening of the Drainage canal, by Professors Zeit and Futterer. The statement is on record in a report of the Massachusetts State Board of Health that typhoid bacilli were found in the tap water as supplied from the running water at Lawrence, Mass. A bacteriological examination as a rule does not absolutely determine whether the water is infected, in fact, generally not. The ordinary assumption among sanitary engineers and experts is that if there are populous communities having their sewage and drainage thrown into running streams, that the streams are infected. I anticipate a very marked increase in population in the Missouri river
2545 valley and its tributaries as well as the valley of the Mississippi and Illinois rivers, and I might add that there is a probability of greater growth on the Mississippi and Missouri than there is in the valley of the Illinois, exclusive of Chicago, so that I think the amount of sewage pollution in each of these rivers—the Mississippi and the Missouri—is likely to increase much in the future.

Q. In their natural state, considering the future, the untreated waters of the Missouri river will be necessarily a menace to the inhabitants of St. Louis as the waters came into the intake, would they not?

A. I shouldn't think that the waters of the Missouri river in their natural state, either in the present, past or
2546 future, would be a menace, but if you mean with the growth of population upon the Missouri watershed, it would contribute additional infection to the Missouri river and cause it to become less healthful and less safe as a water supply, I am perfectly frank to answer, yes. That answer would also apply to the waters of the Mississippi. I can hardly conceive that in the distant future in a stage of very low water, that the Missouri river would become substantially a stream of liquid

sewage. I could conceive that as to the Mississippi a little more readily. This would not depend entirely upon the supposed and anticipated increase of sewage, but upon other considerations—the decrease of the flow of the streams themselves, for one. From the decrease of the flow and the increase in the population, the waters of both of these rivers would be dangerous for ordinary domestic purposes to the inhabitants of the state of Missouri on her banks.

Q. Are there other persons, sanitary engineers, expert in water supplies in this country, who are as familiar with the subject as yourself?

A. I think there are not very many.

Q. About how many?

MR. JEFFRIES: I object to the question as being incompetent, irrelevant and immaterial.

A. At the present moment, I do not think of any whose judgment I would take in preference to my own, or whose judgment I would advise a client to take in preference to my own.

2547 Assuming a certain number of cases of typhoid fever at St. Charles, Missouri and an equal number of cases at Kansas City, Missouri, and consequent typhoid fever in St. Louis, I would attribute the typhoid fever in St. Louis to both St. Charles and Kansas City. Of course I assume that the typhoid occurred in St. Louis at a proper time after the appearance of the other to permit of the connection. Assuming typhoid fever in St. Charles and Omaha and in St. Louis. I would attribute the St. Louis typhoid to both cities. Assuming typhoid at St. Charles and an equal number of cases at Helena, Mont., I would attribute the typhoid in St. Louis to both places.

2548 Assuming 50 cases of typhoid fever at Helena, Mont., and no other possible source in the Missouri river of infection of its waters from typhoid at that time, and that the waters from Helena, Mont., arrived at the intake and that in a proper time after that, there occurred in St. Louis an increase

in typhoid fever, on the hypothesis stated, I should not want to attribute a very large part or more than a very small part of the increase of typhoid fever in St. Louis to the typhoid fever cases at Helena. The life of the typhoid bacilli in streams, is rather a question of time and distance, and as a general proposition I would say that it is my present opinion that there is no stream of water on the surface of the earth flowing in natural channels, that is long enough to warrant the absolute assurance that a typhoid germ might not live from one end of it to the other.

2549 If there were typhoid germs cast into the waters of the Mississippi at St. Paul, I think it is possible to a certain degree that these typhoid germs might arrive at New Orleans and infect the water supply of New Orleans. That is, I think it is possible that some of them might arrive. I would not want to be understood as saying that they would all arrive. One instance in which scientists in water supply have determined to their own satisfaction that the typhoid bacillus has lived in running streams for a distance of over 150 miles is the instance of the pollution of the St. Louis supply by the drainage of the city of Chicago. The pollution of some of the cities on the Merrimac river I believe are traced to distances as great as that. The pollution of the Connecticut river similarly and of the Hudson river.

2550 I am not prepared to make a specific statement that the infection of water in the Hudson river at a given point was caused by similar infection of the Hudson river 150 miles above, but a statement was made to me not very long ago that such was the case, by a gentleman who had made some investigation along those lines. I know of no other instance where the pollution of one water supply or infection was caused by the infection of a water 300 miles above, outside of the case of Chicago and St. Louis that we are considering.

2551 I do not recall of having heard or knowing of an instance in which the infection of a water supply was attributed

to an infection 250 miles above the place where the infection was found to exist. Cincinnati and Pittsburg is an instance where the distance would be about 200 miles or considerably farther apart than that,—somewhere around 300 miles I believe. I think I have seen a statement on what would be considered the authority of some kind of a scientific man that waters of Pittsburg infected the waters at the intake at Cincinnati. My impression is that it was the Board of Sanitary Engineers who were considering the water supply of Cincinnati. I think so, but as I am speaking from memory on that, I won't be positive about it.

CROSS EXAMINATION by Mr. Todd.

2553 In my direct examination I figured the period of time in regard to the Detroit epidemic from the deposit of infectious material in Lake St. Clair to the four deaths occurring in Detroit and stated that the time corresponded within 24 hours for the transmission, incubation and death. A man may contract typhoid fever and not die before two months or perhaps six months.

2554 There are no cases on record that I know of or that have come to my attention where they have died before the end of three or four days after contracting it. I figured the time that these four patients were sick or had been down with typhoid fever before they died, by my study of statistics, regardless of knowing whether those patients had been sick for two or three months prior to death or not.

2555 In my study as a sanitary engineer and epidemiologist I don't think I have enunciated and demonstrated any new principles. I should hardly want to claim that I had been the pioneer in any new departure of investigation in these sciences. I rather think this science of epidemiology and sanitary engineering as to water supply, has not been exhausted. I think there are persons in this country or elsewhere that have made more extensive investigations than myself. If such a person should draw different conclusions than those which I have drawn, unless they were possessed of other facts which are not

known to me, I would certainly consider that they had made a mistake. I consider that in my investigations of the conditions existing between Chicago and St. Louis on the watershed of the Mississippi above the intake that I am in possession of all the facts possible and necessary in this investigation and sufficient to establish the certainty of my conclusions.

2556 If one who has made greater investigation and had broader experience in these sciences than I have and should be acquainted with all the facts with which I have been acquainted, should draw different conclusions, unless he had different information to that which I had, I would consider these conclusions were unwarranted and unworthy of acceptation. I cannot conceive of any different information that could be obtained that would change my conclusions. I do not consider my conclusions in this case as infallible.

2557 If during the years 1896, 1897, 1898 and 1899 there existed upon the watersheds of the Mississippi, Illinois and Missouri rivers typhoid fever that resulted in the death of from 300 to 375 people annually, the presence of such cases would undoubtedly render the water supply of St. Louis unsafe and dangerous for domestic use. For even though the water was treated by what we know to be, and what analysis has shown was an inefficient method of treatment, the typhoid fever death rate and number of cases of death in St. Louis apparently traced to water infection is greater than should exist attributable to a good water supply. Had I been sanitary engineer of the water supply of St. Louis during those years, I should certainly not have recommended this water as a safe water. I should not have advised the people to drink it without further treatment by boiling, filtration or some treatment that would be sure of certainly reducing the possibility of infection from it. Boiling would add very much to the safety of the water. If the water were boiled now, I would consider it would be a safe water.

2558 Q. Is there any way known to sanitary science or epidemiology which can tell or demonstrate that the in-

creased typhoid in St. Louis in 1900, 1901 and 1902, did not come from any one of the cities whose sewage emptied into the Mississippi river above the intake on the Mississippi?

A. There is no method that I am aware of that would enable one to demonstrate that no part of the infection came from any one of the cities in question.

2559 If there were a certain number of deaths from typhoid in Minneapolis and Kansas City each year during the years 1896-7-8-9, there is no means by which it would be possible to determine how much typhoid came to St. Louis from either one or that it did not come from both.

2560 It is not possible to establish the fact that it came from either one of the sources, that is, assuming that there was no existent history that would exclude either one or the other of these places as being the cause of typhoid in St. Louis. If conditions existing between Minneapolis and St. Louis and Kansas City and St. Louis were such as to be the cause of typhoid in St. Louis, there is no way known to my knowledge which can demonstrate whether the cause of the typhoid fever in St. Louis came from Kansas City and not Minneapolis, or from Minneapolis and not from Kansas City.

2561 I should not think it possible that notwithstanding the fact that conditions of that kind might exist as to those two places, that the contagion could come exclusively from Kansas City or Minneapolis. I think it would be impossible to make absolute proof either in the affifmative or negative. Now if we add to those conditions, all the conditions which actually exist along the watershed of the Mississippi river above the intake, I do not think it is possible then to say which one of these cities contributed the largest amount of typhoid existing in St. Louis for the years 1900-1-2. It seems to me that the proportionate share in the increase in typhoid fever in St. Louis from any of the upper cities can be demonstrated without an assumption. I could not say what proportion Minneapolis contributed.

I doubt that I can say what proportion any of the cities contributed outside of Chicago.

2562 Q. Can you show what Chicago contributed without assuming anything?

A. Not the absolute quantity.

Q. Any more than you could for Minneapolis?

A. I think so.

Q. Any more than you could for Kansas City?

A. Any more than for Kansas City, I think so.

Q. Any more than you can for any one of the number of cities, the typhoid statistics of which have been introduced in evidence here?

A. I think so.

Q. Is there a different rule applied by epidemiologists and sanitarians to the city of Chicago than would be applied to all or any of the other cities lying tributary to the water supply of St. Louis?

A. There is not, but different facts are in our possession in regard to the city of Chicago from those which exist in regard to the other cities on the watershed. We haven't got the facts as elaborately in regard to all the other cities as we have in regard to Chicago, but we have them sufficiently for all practical purposes, I think.

2563 The facts that I have about Chicago that I haven't about Peoria are that at a certain time, its sewage was added to the waters which supply St. Louis with its water supply. At that time the sewage at Peoria was being added to the water supply of St. Louis. I am not prepared at the present moment to give figures as to what was the difference as to the volume of sewage from Chicago entering the Des Plaines river previous to the opening of the Drainage canal and that which empties into the Des Plaines river now since its opening. The 4400 cubic feet that I have testified about of fecal discharges represented the solids in the fecal matter discharged into the sewers of Chicago which are tributary to the Chicago river and the

Drainage canal. Some of it undoubtedly enters the Drainage canal, but I do not know what proportion of it does.

2564 I could not say at the present moment positively whether the same territory that empties into the Chicago river the 4400 cubic feet of fecal mater is any different today from what that same territory was prior to the opening of the Drainage canal. I don't know how much or what proportion of that 4400 cubic feet was pumped into the Illinois & Michigan canal prior to Jan. 17, 1900. I am sure all of it was not pumped into the Illinois and Michigan canal prior to the opening of the Drainage canal. I don't know how much of it was. I don't know that I have any judgment at the present time based upon any accurate knowledge as to how much it was.

2565 I don't see how that influences the case any more than knowing the actual amount of infection that may have come from any other source that was continuous before the opening of the canal. I do not know the amount of infection that came from any other one source before the opening of the canal. I couldn't say how much sediment there was on the bottom of the Chicago river at present. I did not consider the sediment on the bottom of the Chicago river as a continually important factor at the opening of the canal. Today it has its importance, but it is not paramount.

2566 I examined the lake front in Chicago in 1892. I know that it is quite materially different in some respects at the present time. The conditions have been considerably improved.

2567 If it should appear that the Chicago river from the entrance to Robey street was of a depth of 26 feet in the channel, with the exception of the tunnels, and the condition has been created within the last three years, I do not think it would have any effect upon my conclusions in regard to the effect of sedimentation in the Chicago river. I don't know what effect the sewage pumped into the Illinois and Michigan canal prior to the opening of the Drainage canal had upon the water supply

of St. Louis, nor how much typhoid in St. Louis could be attributed to it. I think it is safe to state now that the major part of the increase in typhoid fever in St. Louis is due to the sewage discharged through the Drainage canal. By major part, I mean considerably more than half.

2568 I should say that in St. Louis the cases probably increase to about the same extent or the same proportion as the deaths. The increase in deaths would be the most scientific way to consider the question of typhoid. If I have both the deaths and the cases, I say that the deaths are the better criterion because a man never dies but once and under the law, a record of his death is bound to be made somewhere, whereas a man may be sick of typhoid and no record appear, so that records of cases are always deficient. A man frequently has been acused of dying of typhoid, when as a matter of fact he did not have it, but there have been other cases where he died of other causes and they thought he had typhoid.

2569 To a moderate extent, it leaves the whole situation in doubt, but considering these things from a broad practical standpoint they will balance up in a period of years.

Q. If a man has typhoid fever and does not know it, why should the epidemiologist assume the fact that he has it when there is no evidence?

A. The epidemiologist does not assume the fact that he has it.

2570 Q. Assume that 160 deaths occurred in 1900 as against 198 in 1901, would that be evidence that typhoid had increased in St. Louis when the facts are that the number of cases decreased?

A. I should never base concluusions in a typhoid epidemic on the number of cases which are reported, for reasons already stated, and there is no question that an increase from 160 deaths to 198 deaths shows an increase of typhoid in the city. There is no question that the mortality in typhoid is affected by the skill of the physician, the care of the nursing and attendants, and so

on; the asumption is that we are able to handle it better than before and I should say that the probability was that less people would have died of typhoid fever out of the same number of cases, in 1901 than would have died of it in 1900.

Q. Now if we assume that the number of cases, as is illustrated upon the chart that is already in evidence, is true, and that those cases started in 1896 with 291; 1897, 433; 1898, 426; 1899, 908; 1900, 1213; 1901, 1101; 1902, 1112, would you say, as an expert sanitarian, that the typhoid conditions existing in St. Louis for 1900 and 1901 and 1902 were attributed to the Drainage canal of Chicago and not to the same causes which created the uniform increase in typhoid fever from 1896 up to 1899?

2571 Assuming that the figures given are correct, I consider that the records of cases in the city of St. Louis in regard to typhoid prove nothing except that all of the cases were not reported in the earlier years and are not reported now. Assuming that the number of cases which you have stated in your question from 1896 to 1902 were deaths, I would attribute the gradual increase of typhoid fever in St. Louis during that period to gradually increased infection from somewhere. Where from I do not know. I would have to investigate the matter to see. Inasmuch as the condition assumed is contrary to the fact, I have not taken the trouble to investigate it. Supposing that in this number of cases none of them died, that by the best scientific knowledge of today, these cases were ascertained to be typhoid fever, and included all the typhoid in St. Louis, I could not say to what I would attribute the gradual increase of the number of cases from 1896 to 1902 without making a study of the conditions with such facts in view.

2573 In my consideration of this question, I took into consideration the sewage from Peoria. I don't know what the amount of sewage is that enters the Illinois river from Peoria. I do not know how many cattle are fed at Peoria. I could only make a guess. I know that Peoria is a place where cattle are very extensively fed. I have not particularly investi-

gated the character of the sewage that comes into the river at Peoria. There is some difference in the sewage from distilleries and slaughter houses and the sewage from glucose factories. There would likely be acids discharged into the river from a large glucose factory. I do not know in what quantities. It would be likely that acids would be discharged into a river from distilleries.

2574 The effect of the discharge of acids in a stream the size of the Illinois from large distilleries and glucose factories at Peoria upon the life of the typhoid bacillus would depend very much upon the alkalinity of the water in the first place. Under some conditions it might tend to prolong it; under other conditions it might tend to decrease the life of the bacillus. I have not personally made any experiments under those assumed conditions. I am not aware of any one, at the present moment, who has made experiments with the typhoid bacillus in water impregnated with the sewage discharged from a distillery or glucose factory. I am not able to say positively whether that discharge would tend to increase or decrease the life of the typhoid bacillus. It might do either.

Q. Then if you are not able to say whether it would or it would not, can you say whether or not a typhoid bacillus on his journey from Chicago to St. Louis coming in contact with the sewage laden water at Peoria from the distilleries and glucose factories, would be able to live the journey?

A. I cannot say whether a specific typhoid bacillus would or would not be able to live under the circumstances assumed.

Q. Can you say whether a whole tourist excursion of those bacilli would live or not?

2575 A. I think it is entirely probable that some of them might squeeze through. I base my doctrine of probability, in the absence of any specific knowledge as to whether the individual bacillus would live in a medium of that character, upon the fact, which is very evident to my mind, that certain typhoid bacilli started from Chicago have lived, passed through the Illinois river and infected the water supply of

St. Louis and produced typhoid fever in those who have used it. I think we have pretty nearly proved in this case that the typhoid bacillus that left Chicago arrived in St. Louis. I don't know that I want to say that by my own individual self I have proved it, but I think it has been proven. I don't think that anybody knows very much more about this subject than I do. The typhoid bacillus that leaves Chicago, in order to get into the intake tower of St. Louis, must pass by Peoria. I do not know how many distilleries empty their filth and sewage into the Illinois river at Peoria. I do not see that it is of any importance whether there is one, one hundred or one thousand in that case.

2576 Moderately, I have some knowledge of the character of the sewage that comes from a distillery. I should not expect a typhoid bacillus to live in that kind of sewage a great while. I have a moderate idea of the character of sewage that comes from a glucose factory. I could not say whether a typhoid bacillus will live in that medium any length of time.

Q. Have you ever been able to identify any bacillus of typhoid found in the Mississippi river above the intake as being indigenous to Chicago and not coming from the other towns located upon the watershed of the Mississippi river, above its intake, the Missouri and Illinois?

A. Certainly not, and it would be absolutely impossible to do so any more than it would be possible to determine from what source a potato came that you might find floating in the river.

Q. Would the fact that you found a potato floating in the river prove that it came from Chicago?

A. Certainly not.

2577 Have never known of anybody catching lockjaw from drinking the germs of tetanus. I believe it is not contended that people get it by taking it in through the alimentary canal.

2578 As to whether it would have any effect on the health of the man who drank it, would depend upon the condition

of his intestines. It would affect him if he had a raw place in his throat due to a cold or something of that sort. Assuming that there should be typhoid fever in New Orleans and two months before, one case of typhoid fever appeared on a steamer in Lake Itasca—the source of the Mississippi—and there were no other cases of typhoid fever between that point and New Orleans, and no other source of infection, I am afraid I would have to attribute the cases in New Orleans to the case in Lake Itasca. These things do not originate of themselves.

2579 I don't think I ever heard of a case of anthrax in Chicago. I am free to say that I have not heard of a case coming from Chicago. I regard the sewage of Chicago as a greater menace to the inhabitants of Missouri than the sewage discharged by St. Louis into the Mississippi river would be to those living south of St. Louis. Assuming that Chicago sewage should be cut off, the water of the Mississippi river on the Missouri side, after it had received the sewage discharge of St. Louis would be unfit water to drink. I do not know that there is any more liability of anthrax or hog cholera occurring in Chicago than in St. Louis. It is entirely possible that if they did get hog cholera along the southern border of Missouri, south of St. Louis along the Mississippi, that it would come from St. Louis more likely than Chicago. I should look in St. Louis for the source of infection before I looked in Chicago. I believe that Chicago is more likely to get Asiatic cholera than St. Louis in event of its coming to this country at all.

2581 In regard to the case of anthrax I spoke of, appearing in St. Louis, I think it was due to the water of the Mississippi. It was attributed to the water by the man who had the case,—a physician here in town by the name of A. Ravold. Dr. Ravold attributed it to the water as being the most probable source. The case referred to was that of a woman who was scrubbing a sink and got a piece of slate in her hand. It was proved to be a case of anthrax. Inquiries were made to ascertain the source, and it was impossible to ascertain that there had been anything in the neighborhood of

the sink that might have communicated the germ; at least it was not ascertained that there had been, other than the water,

2582 and knowing that bacillus had already been found in the waters of the Illinois river, it is at least a moderately justifiable assumption to say that it may have come from the water, and in fact, very probably did. I would not say for a minute, from the history of the case as I got it, that the water is the only explanation. I could not say whether it was attributed to the water of the Illinois river. When I look into the future I should not be surprised to see an anthrax epidemic in Missouri, understanding that there has been an epidemic of it in Missouri in the last few years. I could not say whether that was before or since the opening of the canal.

2583 I have personally investigated four or five epidemics. There is no school in this country that I am aware of which graduates a student with the degree of epidemiology.

RE-DIRECT EXAMINATION by General Crow.

I stated in answer to Judge Johns' question that I only found recorded in the official records two cases of typhoid fever in the year 1891 in Port Huron. They made no regular reports in Port Huron prior to 1893 I think. The two cases in 1891 seem to have been accidentally reported by somebody to the State Board of Health.

2584 There is no doubt that there were other cases in 1891 and prior to 1891 for several years, of typhoid fever in Port Huron. (Witness refers to report of State Board of Health, wherein reference is made to cases attributed to infection from Port Huron, in various years.)

2585 I estimate the least time, under conditions as they ordinarily exist, that water would flow from the point where the material dredged from the Black river in front of Port Huron, was dumped into St. Clair river, down to the intake of the waterworks of Detroit in 1892, would be some-

where in the neighborhood of 8 days. I think it is entirely possible that the water passing through the Illinois and Michigan canal in 1899 may have contributed somewhat to the typhoid in St. Louis. It very evidently did not contribute very largely because the typhoid in St. Louis was not excessive during those years. Moreover that amount of water passing into the Illinois and Michigan canal at Bridgeport was not sufficient to take care of anywhere nearly the sewage of Chicago.

2586 My impression is that some of the sewage of the Sanitary District still goes into the Illinois and Michigan canal. The elevation of the crest of the Copperas Creek Dam is given as 149 below the dam, and the Marseilles dam is given as 101, speaking of the river level of course.

2587 I should certainly consider, in determining whether or not Chicago sewage infected with typhoid germs would be likely to infect the water coming into the intake tower of the St. Louis waterworks, the time factor, that is, the time in which it would take water bearing infected sewage to flow. I should consider the time factor as one of the most important ones, in fact, next to the fact that infection was put in, I think I should consider the time it took to get somewhere else. When I stated to Mr. Todd that there are no facts that could be educed or come to my knowledge as to the prevalence of typhoid fever in the cities from which the complainant has introduced reports from the watershed tributary to the intake of the St. Louis waterworks, which would affect my judgment materially, I meant to convey by my answer that it did not seem to me possible that any facts could be educed which had not already been considered that would have a sufficient importance bearing upon the question, to change my opinion on a general proposition. I did not mean of course that my opinions were not subject to modification as additional facts might be brought out.

2588 I found from the statistics that the increase in typhoid fever in St. Louis has been regular and continuous since the 17th of January, 1900 and that up to the very last date

of which we have a record, it shows it is continuously increasing. Any one in studying the conditions of nature is compelled to look for a cause for every effect, and if it were found that certain diseases were increasing the natural inference and proper assumption would be that there was a continuing and increasing cause for the existence of that disease, and if it should prove upon investigation that at a certain time this increase began, we should look at that time for the beginning of the cause which was leading to the increase.

RE-CROSS EXAMINATION by Mr. Todd.

In my investigations in regard to increase, I take into account the number of deaths. If the number of deaths should show an increase and the number of cases a decrease, or normal condition for 1901 and 1902, I would say, as I have stated alread, that I consider the death record decidedly more reliable than the record of cases. It is not a question of diagnosis; it is a question of report and a question of ascertaining the cases. If it should appear that the cases reported were the correct number of cases existing and the cases reported were correct diagnostications of the cases, I should consider that in all human probability the death standard would be the safer one to rely upon. If it were absolutely proved that the other were the case, that is that the number of cases represented all the cases, and that the probability of a correct diagnosis was the same as in the case of death, I should then give the record of cases an equal weight with the record of deaths.

2589 (Complainant offers a certified copy of typhoid fever death rates for the various years previously stated, at Kansas City, Missouri; St. Charles, Missouri; Council Bluffs, Iowa; St. Joseph, Missouri; Lincoln, Nebraska; Omaha, Nebraska; Chicago, Illinois; Davenport, Iowa; Moline, Illinois; Rock Island, Illinois; Galena, Illinois, and Warsaw, Illinois.)

(Complainant's exhibit 22 is withdrawn for correction, defendant's counsl consnting thereto.)

2602 GEORGE W. FULLER examined in chief by Attorney General Crow.

2603 Am sanitary expert. Professionally educated at Massachusetts Institute of Technology in Boston and University of Berlin, Germany. Have received an education as Bacteriologist, although that is not the particular branch of sanitary work which I gave the most attention to while at the Institute of Technology. That was the principal topic which I studied in Berlin. It was from the department of chemistry that I graduated at the Institute of Technology in Boston. In regard to the necessity and advisability of treating water supplies by artificial processes, I would say that I have given that matter special attention and with regard also to plans and specifications. (Witness states his further education, knowledge and experience.)

2606 Am familiar with the general features regarding the source and method of treatment of the water supply at St. Louis.

2608 As a general proposition, it is my judgment that the best index to the sanitary character of a public water supply is the mortality record from water-borne diseases in the community using the water supply in question, and especially the mortality statistics of typhoid fever. It is my experience that the typhoid fever mortality statistics are preferable to those of other water-borne diseases for a number of reasons, of which the principal ones, are the wide-spread nature and distribution of typhoid fever, its abundance in those communities having supplied to them sewage polluted waters; the well defined character of the disease, taking everything into consideration, and also the substantially large percentage of deaths to those who have the cases, that is, the percentage of deaths to cases is larger than in some other instances. From twenty-five to thirty thousand deaths result annually in the United States from typhoid fever. The number of cases occurring in this country annually I would place at more than a quarter of a million. It is my judgment that the water supplied to the citizens of St. Louis by the municipal water department during the years 1895 to

1899 inclusive, was what might be called a good sanitary water.

2609 I base that judgment on the fact that during the period mentioned the typhoid fever mortality statistics showed as low a rate, approximately speaking, as in the case of quite a number of other American cities having a pure or very nearly a pure water supply. The treatment of the water during that period consisted of settling the water in the basins at the Chain of Rocks. The result of this settling was to improve the water to a considerable degree as regards the elimination both of mud and bacteria, including those of a pathogenic nature, when such were present in the raw river water. There was substantially no change in the period for sedimentation during the years in question. Pathogenic bacteria, as used by me, include water-borne bacteria that might convey infectious diseases such as cholera and typhoid. In my judgment the raw Mississippi river water as it entered the intake during this period was a much less safe water from a sanitary standpoint than was the water after it had been treated in the settling basins. This was due, of course, to the elimination of bacteria of an injurious nature by the processes of sedimentation, and in which process the

2610 injurious bacteria subside—falling to the bottom of the basin and from time to time are removed and thus prevented from passing on to the water delivered to consumers. These deposits are removed by artificial means once or more each year, by emptying the basins and flushing the mud into channels which conduct it to a sewer leading from the end of the basins to the river and down below, a considerable distance below the intake tower. I will classify this raw river water as it entered the Chain of Rocks intake tower during the years 1895 to 1899 inclusive as a suspicious water, meaning by that, not distinctly a good water, but one in which there is a liability of danger from time to time to those who drink it in its raw condition.

2611 The average annual deaths from typhoid fever from 1895 to 1899 inclusive is 112. During the three years, beginning with Jan., 1900, it is 196, showing an increase in the number of deaths of about 80%. Taking into consideration the differences in population, that is, the increasing population during that period, and expressing the typhoid fever deaths with reference to the number per 100,000 of population living there has been an increase during the past three years on an average, of about 60 per cent over the annual typhoid fever death rate per 100,000 population living, for the five years, 1895 to 1899 inclusive. Comparing the number of deaths from typhoid fever during these eight years, with reference to the total number of deaths from all causes, occurring in the city of St. Louis, and obtaining the percentage mortality from typhoid fever, the percentage increase for the last three years on an average as compared with the average percentage of mortality from typhoid fever during the five preceding years, is 73 per cent. I will further state that the average number of deaths from typhoid fever in St. Louis during the first five years under consideration was about 20.4 per 100,000 population living, and that this rate during the past three years, on an average, was about 32.3 on the same basis; that is, the average number of deaths per annum per 100,000 population living. In my judgment, the three methods of investigating and comparing typhoid fever statistics when considered together afford a proper and reasonable basis upon which to base conclusions with reference to typhoid fever statistics of the city for the reason that each throws light on the matter, but the data regarding the two last methods of comparison taken together are the fairest and best way.

2612 I should say in round nunmbers there has been an increase during the second period under consideration of about sixty to seventy per cent above the average rate in the earlier period mentioned. The number of deaths by months for

1903 up to and including Ma, clearly indicate an increase in typhoid fever in this city.

2613 The record of number of deaths from typhoid fever in St. Louis by months shows a continuance of these comparatively high figures to an unusual degree, showing that for this season of the year, there is an unusual prevalence of this disease in this city. I ascribe the increased mortality from typhoid fever in St. Louis since Jan., 1900, to an increased amount of infection in the water supply, and predicate this opinion on the practically uniform distribution of the homes or residences in which the typhoid deaths have occurred in St. Louis and the further fact that a careful examination of the other several possible sources of typhoid fever, show that no substantial portion of this increase may be explained in that way. I consider that the sanitary character of the public water supply delivered to the consumers in St. Louis has been less safe since Jan., 1900, than it was formerly. It is my judgment that this water as delivered to the consumers since Jan., 1900, cannot be classed as a good water. The treatment of the water since 1900 has been essentially the same as it was before. I consider that the sanitary character of the raw Mississippi water entering the intake tower of the St. Louis waterworks since Jan., 1900, has been distinctly and decidedly less safe than during the five preceding years.

2614 The principal source of dangerous impurities in public water supplies in raw condition is sewage pollution. I am familiar with the typhoid fever statistics in the larger center of population on the Mississippi watershed above the Chain of Rocks, excluding the Sanitary District of Chicago, since Jan., 1900. Taking the statistics upon this watershed area based upon the average number of deaths from typhoid fever per year, it is my judgment that there has not occurred on such area, any increase in the number of deaths sufficient to explain to a material degree the less safe condition of the Mississippi water at the intake tower during the last period as compared with the

period from 1895 to 1899. In my judgment it is the Chicago Drainage canal discharging sewage and drainage containing filth and infection from Chicago which makes the water in its raw condition at the intake tower less safe than it was preceding Jan., 1900.

2615 There have been about 1647 deaths from typhoid fever in Chicago since Jan., 1900, and the infectious discharges from the persons sick and dying of typhoid fever, have to a very large degree been disposed of by their passage through the sewers to the Chicago river and the Chicago Drainage canal.

2616 In round numbers, I place the figure for those people who sewer directly into the Mississippi, its branches and tributaries above the St. Louis waterworks, exclusive of the Sanitary District, at about 2,700,000. This figure is based upon a separation, on an average of the sewage contributing population from the rural population by taking towns of 4,000 and over as representing those who have sewage systems and contribute sewage directly to the water courses. I include in this number the Missouri river and the Illinois river, exclusive of the Chicago Sanitary District, as well as the upper Mississippi. (Witness states reason for drawing the line at cities having population of 4,000.) In round numbers I estimate an increase of 60 per cent in population sewering into the Mississippi valley above St. Louis, due to the Chicago Drainage canal bringing sewage of Chicago into the Mississippi watershed. I place the figure as to the time required for the Chicago sewage to flow from Lockport to Grafton—291 miles—at from 10 to 25 days. The average time required, in my opinion, is about 15 to 18 days.

2618 I consider that the typhoid fever germs may and do continue to live for weeks and months in sewage polluted waters. Generally speaking, it is my opinion that there is not any very great difference in the life history of the germs of Asiatic cholera and typhoid fever. At times the flow of the drainage canal exceeds the flow of the Illinois river and there consequently results at times, a dilution of the Chicago sewage by

the Illinois river, and at times, a dilution of the Illinois river by the contents of the drainage canal. Dilution at best does not destroy disease germs or infectious matters. Its effect is to minimize the danger to those who may drink of the water so diluted. One effect of the dilution existing in the Illinois river at low stages is to bring to Grafton more quickly than would otherwise be the case, injurious matter entering the Illinois river at points along the route of its flow and also entering the Illinois river from cities and towns located upon the tributaries of that river.

2619 The most significant feature of the ponds, dams and slack water stretches which are found in the Illinois river, is the low velocity of flow of the water, at times of low stages of the Illinois river. There are a good many days in the course of a year when these velocities at the places above referred to are so low that deposition takes place to a considerable degree, of the bacteria and other matters suspended in the water, and which to a large degree are derived from the contents of the Chicago drainage canal. The deposition of these bacteria including those of infectious diseases like typhoid fever, does not mean their permanent elimination and removal from the flowing water. The reason of this is that as they reach the bottom and lie upon the bed of the stream they are disturbed from time to time, due to changes in velocity of stream flow, such as caused by moderate rains, or by the passage of boats or the action of the wind and the like. The resulting disturbances cause the bacteria to leave the bed of the stream in which they may rest for some time, bringing about a return of those bacteria to the flowing water. In this way the germs of disease may pass from the Chicago drainage canal at Lockport to the mouth of the Illinois river at Grafton. I believe that typhoid fever germs disappearing from the flowing stream and becoming deposited in the bed of the river are able to live there for weeks or months. In my judgment, it is not only possible but probable that the water of the Illinois river, as it flows into the Mississippi may sometimes be richer in typhoid fever germs

derived from the Sanitary District of Chicago and coming through the drainage canal, than was that portion of the water drawn from the drainage canal when it flowed over the Bear Trap dam. Such a condition of affairs made and at times probably does arise through the disturbance of the sediment lying upon the bed of the stream in places, which sediment may and undoubtedly does at times contain relatively large numbers of typhoid fever germs.

2620 As these typhoid fever germs are returned to the flowing stream from their position in the bed of the river, there is effected an accumulated result whereby at times at least the waters of the Illinois river flowing to Grafton may discharge the concentrated essence of the infection of the Chicago sewage by taking in the manner above described, portions of the infection coming from many days' flow of the drainage canal into the Illinois river. I know of no instance connected with public water supplies in which sedimentation is employed for the purification of sewage polluted water without any provision being made for the removal of the sedimented materials so that they will not re-enter the water as it leaves those basins. Without such means of removal, the object and purpose of the settling basins entirely fail. I do not believe that the conditions from Lockport to Grafton are sufficient at all times to prevent infected materials coming through the Chicago drainage canal and entering the Mississippi valley at Lockport, from reaching the Mississippi river at Grafton. It takes a fraction of one day in the ordinary stage of water for the Mississippi river to flow from Grafton to the Chain of Rocks—a distance of 29 miles.

2621 I do not believe that it is possible for the Illinois river water to flow by the Chain of Rocks without some of it ordinarily entering the Chain of Rocks intake tower.

Q. Mr. Fuller, in view of all the facts and conditions as you know them, do you or do you not consider that the sewage of the Chicago Sanitary District pollutes and infects the water of the Mississippi river along the Missouri shore, and especially

at the Chain of Rocks intake tower of the St. Louis waterworks, to such an extent that it makes the Mississippi river water less safe for drinking and domestic purposes than it was before the opening of the Drainage canal?

JUDGE JOHNS: I object to the question as requiring the witness to determine what is to be ascertained by the United States Supreme Court on the trial.

A. It is my judgment that it does.

2622 Assuming that for the years 1900-1-2 there was no increase in the number of typhoid deaths on the watershed of the Mississippi river above the intake, exclusive of the Sanitary district of Chicago and that there were 1647 typhoid deaths for these three years in the city of Chicago, it is my judgment the typhoid infection coming from Chicago and passing through the Drainage canal by way of the Des Plaines and Illinois rivers to the intake tower had an influence on the typhoid fever death rate in St. Louis and that it is the cause of the principal portion of the increase during the past three years. Assuming that the population of the Chicago Sanitary District grows larger and that the amount of Lake Michigan water and sewage, etc., is correspondingly increased, I am of the opinion that the water at the intake tower would be rendered less safe than at the present time, due to the increased amount of infection entering the Mississippi watershed from Chicago, and to the

2623 shorter interval of time required for the passage of that sewage from Chicago to the intake tower. Such increased sewage caused by the increased population of Chicago would make the Illinois river and the Mississippi river at low water stages a much less safe water, generally speaking, than at the present time. It is quite possible that looking far enough into the future, this amount of pollution would become sufficient to exceed the oxygen and to make it in many ways resemble an open sewer—that is to say, it would be a stagnant pool resembling sewage rather than a live active water containing atmospheric oxygen. In my judgment the increased amount of infection coming into the Mississippi river from the city of Chi-

cago's sewage at the present time makes an added responsibility as regards the treatment of that water, to make it perfectly safe and wholesome as supplied to the citizens of St. Louis. Such treatment of the water would involve, I think at the present time, more responsibility, and in a financial way, it would be shown by the greater expense of supervision of a filtration plant, and the added cost of supplies used in connection with the operation of filtration works, especially at times of low water.

2624 Looking into the future, there will be a time when single filtration will not be sufficient to produce a satisfactory quality of water at the Chain of Rocks excluding the water from the Sanitary District of Chicago. It is certain that the added infection from the Chicago sewage will hasten the day when single filtration at St. Louis will prove unsatisfactory and when it will be necessary to give attention either to double filtration or to other methods involving increased expense and increased responsibility.

CROSS EXAMINATION by Judge Johns:

My opinions are based on the assumption that the waters of the Illinois river are so polluted with the waters of the Drainage canal that they cannot purify themselves by the time they reach the intake at St. Louis, if they ever do, but with the idea that that degree of purification can take place at certain times—not at all times. There may be and may not be times in the Illinois river in the flow of the water from Bear Trap Dam to the intake tower at St. Louis when that water would free itself of infection, if any infection existed—I don't know.

2625 I doubt if there is any season of the year, any rate of flow or any stage in which it might happen. At times I certainly believe that infectious matter flowing from the sewers of Chicago into the Drainage canal will certainly arrive at the St. Louis intake. In order to provide against that contingency, some means of filtration or purification of the water should be adopted at St. Louis in order to get those particular germs out. It would be desirable to filter the water supply of St. Louis if

it was received only from the Missouri, but it is not necessary in order to get a reasonably good water, as has been shown by the typhoid statistics and experience during 1895 to 1899. In order to get a thoroughly satisfactory water without liability of pollution from time to time, the waters at the intake, if consisting only of Missouri water, ought always to have been treated by other means than sedimentation, but it is also true that before 1900 they got a reasonably good water without filtration, but with the sedimentation.

2626 The typhoid fever in St. Louis prior to 1900 was due to a variety of causes. There is a residual number of typhoid deaths in American cities which are not ordinarily eliminated even with a pure water supply and they are still found in cities which are now provided with good water supplies. If the Illinois river and the city of Chicago did not exist, and the problem before the people of St. Louis now was what to do with their water, I think it ought to be treated in order to get a thoroughly satisfactory water, but as I have said, sedimentation from 1895 to 1899 gave them a reasonably good hygienic water. Sedimentation from 1895 to 1899 I would hardly say gave them a reasonably good water at all times. Judging from a sanitary standpoint, I should be inclined somewhat to doubt that sedimentation from 1870 to 1885 gave St. Louis a reasonably good water.

2627 The germ theory of disease became generally recognized in the United States among sanitary engineers in the late eighties. They have been learning all the while and are still learning. There is a possibility that in the future, the practice of filtration would have to be abandoned and sewage destroyed at its origin. Looking into the future, it is possible in low water that the Missouri river might become a stream of liquid sewage but that would be a long way off; it would be very highly sewage polluted no doubt. The same is true of the Mississippi.

2628 It is possible that the Illinois river might become a stench to the nostrils of the people, in which case there

is a possibility of quadruple filtration being necessary if St. Louis persisted in taking its water from these rivers, but as I have stated it is also possible that other types of purification might be required in connection with filtration. I believe that typhoid bacilli entering the Drainage canal at Chicago not only may be, but are transmitted to the intake at St. Louis. It is a question of time interval and not distance which is the controlling factor in this proposition. Given a sufficient distance and a sufficient time in running water, and taking the proposition independent of dilution, there would be a very large reduction ultimately of typhoid bacilli, but whether those germs would be wiped off the face of the earth that way, it seems to me is very doubtful.

2629 If a stream of water of 300,000 cubic feet per minute, into which was poured the sewage of Chicago, was started in a tortuous course of a small river at Bear Trap Dam and received no dilution on the way, I do not believe it would be absolutely freed of infection by the time it reached New Orleans. There would be a greater reduction though, in the number of typhoid germs present. If the sewage of Chicago was poured into the Mississippi river at St. Paul, it would purify itself to a large degree by the time it got to St. Louis, but I don't think it would be absolutely purified. It would be dangerous to the people taking water at St. Louis, in the sense that the liability of trouble would always exist to my thought. Absolutely speaking I think that such a thing as the purification of a stream of running water into which infection is poured by sewage is a very doubtful proposition. In order to be absolutely safe, I think the water ought to be filtered.

2630 If there were typhoid bacilli in the Missouri river and the water supply of St. Louis was taken from the Missouri river only, I should advise filtration or some treatment of that water. If there were typhoid bacilli in the waters of the Mississippi and Missouri and the water supply of St. Louis were taken from those two streams without the intermixture of the

Illinois river water, in my judgment it still ought to be filtered. I do not have any idea of the average proportion of Illinois river water passing the intake. I don't think that I would express any figure off-hand. I should think it would be very likely in the vicinity of one-twentieth of the entire body of water that passes the intake.

2631 If I were providing a filter against Missouri river water only I would not make it larger and more elaborate because of its present condition of infection. The same with reference to the Mississippi river water and with reference to the Mississippi and Missouri river water combined, without the Illinois river water.

Q. Would you make it larger and more expensive in its construction if the Illinois river were so included, at the intake at St. Louis?

A. The way that would probably come about in practice is that there would be no very marked difference in the size of the first installation; but the reserve portion of the first installation would serve for a shorter period of years, due to the presence of the Illinois river water and its pollution, than would be the case without that water.

2632 As a general proposition if you are going to manage a filter you ought to have pretty good men to do it and you ought to do it the best you know how, having regard to the health of the people who are to drink the water, but ordinarily a water that can be easily handled by filtration and where the possibility of a slight deterioration in the quality is not a serious matter, it is very seldom in practice that the expense of the organization would be so great. The proper filtration of southern and western waters depends very much upon the skill with which the coagulant is adjusted. The adding of a coagulant is necessary for the water supply of this city at the St. Louis intake, or the Missouri river. There is required some skill and judgment in the man who manipulates the coagulant.

2633 It would require much more skill and judgment to add the coagulant to the filtration of the combined waters

of the Mississippi and Missouri and would require still more skill to filter the waters of the three rivers combined. The additional expense would be for the payment of the increased amount to the men who had sense enough to do it and to the members of the staff who would take the responsibility in detail during the 24 hours of each day and each day of the week and each week of the year. I endorsed a project for St. Louis involving mechanical filters following sedimentation of the river water and then coagulation and supplementary subsidence and that this mechanical filtration should be by gravity.

CROSS-EXAMINATION by Mr. Todd:

2634 There should be more experienced and more able men operating the filters here in St. Louis, should the Illinois river containing its infection, become a factor. If twenty men were required to handle the filters I suppose somewhere from four to six would require extra skill. I hardly think that the man at the head of the plant would have to be as skillful and intelligent to operate that plant for the filtration of the waters of the Mississippi and Missouri, as he would have to be if the Illinois river water was added.

2635 The cost of securing a man to operate such a plant would be between the limits of $2,500 and $5,000 a year. I do not know of any man who operates a filter such as would be operated here, in filtering the waters of the Illinois, Mississippi and Missouri, nor of any conditions that would be exactly parallel.

2637 It would cost several thousand dollars a year additional in the management of the plant, if the waters of the Illinois were to be filtered in connection with the waters of the Mississippi and Missouri. The entire additional expense of operating the plant if the waters of the Illinois were filtered would be from twenty to twenty-five thousand dollars. I could not tell you accurately what per cent of the waters passing the intake consist of Illinois water.

2638 I think there may be some days in the course of a year when the waters of the Mississippi and Missouri are more infectious than the waters from the Illinois.

2639 I think there is some Illinois river water at the intake at all times. I think that the general average for the year would show a smaller percentage of Illinois river water than the Missouri and the Mississippi river water combined in the St. Louis intake.

2640 I can conceive of times when the sewage discharges of Kansas City would be a great menace to the public health of St. Louis. If there should be an epidemic in Kansas City, to a certain degree it would be a menace to the water supply of St. Louis. Under average conditions it would take in the neighborhood of a week for the sewage to come from Kansas City to St. Louis. Assuming that in Kansas City there should be an epidemic of typhoid fever and the filter system such as I would construct for the filtration of the Missouri and Mississippi waters, was operated by a less skillful crew than would be established there when the combined waters of the Illinois and Mississippi waters would be filtered, I should hope the filters would be a protection to the public health of St. Louis; under those conditions so operated, I think they would.

Q. Then if the crew that you have mentioned would be able to compete with the epidemic at Kansas City within seven days' journey from the waterworks of St. Louis, why couldn't that same crew protect the city water supply when filtering the waters of the Illinois?

2641 A. It is possible that they might, but there would be the added danger from the Illinois river water in that is intermittently flushing out large accumulations of sediment making the water here much more dangerous than it would in connection with the Kansas City epidemic. When I look into the future I have no pessimistic views about the growth of Kan-

sas City. With its near proximity to St. Louis in point of time and the possibilities of it getting a typhoid contagion, as a general proposition Kansas City is a danger and menace, present and impending to the water supply of St. Louis. I do not consider that the water in the Missouri river at the present time is a fairly safe water.

2642 With the treatment that it receives from the water system existing in St. Louis I should not pronounce it as a safe and usable water in absolute terms, but practically speaking, and based on the experience from 1895 to 1899 I would say that it would be reasonably safe. Practically speaking I consider a filter plant such as we have talked about, absolutely safe, but there is no such thing as an absolute germ-proof filter on a large scale.

2643 The waters of the Missouri, with the typhoid conditions existing from 1893 to 1899 along the watershed of that river, would not be absolutely safe water, after having been treated in the Chain of Rocks settling basins, but I think it would be a reasonably good water. I would consider the waters of the Missouri, after that period so treated, as reasonably safe. Assuming that I was sanitary engineer of St. Louis and they were about to adopt a plant like the one at present in operation and conditions existed along the Missouri river such as I am acquainted with, and the water supply was to be taken from the Missouri river, I should probably recommend that they adopt filtration in connection with it. Assuming the same conditions with the water being taken from the Missouri and Mississippi, excluding the Illinois, prior to 1899, I should still think it would be a reasonably safe water.

2644 Assuming that the water supply came from the Missouri, Mississippi and Illinois rivers, excluding the Chicago sewage, I should still think the water would be safe and usable with the sedimentation which takes place. I think that the sewage poured into the Illinois & Michigan canal prior to 1899 contained infection in a considerable proportion but a large proportion of the infection remained undelivered in the Chicago

river. The contents of the Chicago river pumped into the Illinois and Michigan canal were in such a state of advanced decomposition that the proportion of typhoid fever germs originally present in that liquid was comparatively small. The sewage pumped into the Illinois and Michigan canal and then into the Des Plaines river was not absolutely free from infectious germs dangerous to St. Louis, but measured by the infection from 1895 to 1899 at the Chain of Rocks and taking it in connection with the infection coming from the Missouri, Mississippi and Illinois, all these together resulted in a polluted water at the intake tower, but which degree of pollution was not such but that the sedimentation protected the citizens of St. Louis from any serious trouble from typhoid.

2645 If in the watershed of the Illinois, Mississippi and Missouri rivers for 1897, exclusive of Chicago, there were 374 deaths from typhoid fever and as high as 148 in Minneapolis, in its raw condition the water supply of St. Louis was menaced to a certain degree. It was not absolutely free from infection and the liability of infection, but that degree of infection was not such but that the sedimentation which the city waterworks provided could protect reasonably the water consumers of St. Louis. Assuming that the typhoid bacilli discharged from 3740 cases during an average period of fourteen

2646 days was dumped into the watershed of the Mississippi river above its intake, it would pollute the waters of the Mississippi somewhat no doubt; it would be bound to. As to how long it would take that water thus polluted, placed in a sediment basin, to become pure, safe and usable, I don't think any one can answer specifically but it would be a very much longer period than almost any one would be inclined to think, for sedimentation basins holding thirty days' supply are not able uniformly to protect water consumers in such instances where the waters entering such basins are sewage polluted and infected.

2647 The water remains in the settling basins of St. Louis between two and three days. During that time the water

is never in a perfectly quiescent state. If all the typhoid germs we are talking about up the several rivers, continue to live and reach the intake tower, the time they would remain in the settling basins would not be sufficient to eliminate them.

2649 A typhoid germ that got into the sedimentation of the settling basin would live there a good long while in all probability. If the water is slightly typhoid infected it would be liable to accumulate a great many of these germs during the course of six months in the sediment.

2650 With such a wind phenomena as we have had during the last two or three weeks passing over these basins, it would have a tendency to stir at the bottom. Provided the churning action of the wind were to get the sediment in there, the water containing these typhoid organisms would be liable to be carried into the outlet and distributed to the people of the city.

2651 A fair general average of the time the water has to settle in these basins would be a day and a half. A day and a half will do very well as far as sedimentation alone is concerned, and it undoubtedly does eliminate a very large number of typhoid germs. The lakes upon the Illinois river and the back water of the different dams in the river would affect the same result, provided all the conditions were the same. Nature would work the same in the two instances. There is a great deal of elimination from the flowing stream of typhoid germs and other bacteria as the water of the Illinois river passes through those basins, but at the Chain of Rocks the sediment is removed by draining the basins and washing them out.

2652 On the Illinois river, the typhoid germs and other bacteria which leave the flowing water and go to the bottom are subsequently flushed out by conditions which naturally occur on that bed, and are returned to the flowing water and many of them doubtless reach the mouth of the stream. I know that it is so from common sense. When these germs sink to the bottom of the lake and the sewage pollution sinks down with

them, I presume there is quite a little chemical action going on at the bottom where these microbes are. The anaerobic bacteria have an effect upon the destruction of the typhoid bacilli under conditions such as would obtain in a septic tank or in the Illinois and Michigan canal, but in the bed of the Illinois river where such septic action does not ordinarily, if ever, obtain, I do not think that they would affect the life very materially of the typhoid fever germ. This back water caused by the dam, if my memory serves me right, raises the water some forty or fifty miles back. When the water is not at flood tide in the Illinois river, the current through these back-water basins gets down to less than half a mile an hour.

2653 During those times, sedimentation can and does take place to a considerable degree and the bacteria of typhoid would go to the bed of the river, if they settled—a great many of them would settle. When these settling basins extend over surrounding country where vegetation and grass are plenty, some of these organisms would get out among the grass and when they got out there, it is possible that a freshet would drive them back into the center of the stream, but I think more of them would not go back than would.

2654 The percentage removal of bacteria on an average in the settling basins of St. Louis would be in the neighborhood of 75 per cent. The water used in summer in St. Louis is somewhat in excess of that used during any other period of the year. During those months, the time of sedimentation in the settling basins would be less. I am acquainted with the conditions that obtain in what is known as Lake Joliet.

2655 The current through Lake Joliet goes down to a fraction of a mile, at times. It gets quite rapid at times—very rapid. I presume several miles per hour. I should think that a current of several miles per hour would remove a considerable portion of the bacteria.

2656 When the sewage of Chicago passing through Lake Joliet when the current was only a mile and a quarter or a mile and a half, there would probably be some considerable removal

of those germs rrom the flowing stream. It is possible that part of the germs that entered would be scattered and disseminated over that part of the lake which is not adjacent to the current. After it passes Lake Joliet, the first dam it would reach, the principal of which extends for several miles or more, would aid in the removal of germs at times, when the velocity of flow was small, and such velocities at times do occur in my judgment. I suppose those times would aggregate upwards of half a year. When these back-water pools spread out over the country, overflowing the land, the germs that settle along the shores and on the over-flowed land would be less likely to be disturbed by freshets than those just deposited in the bed of the stream, but I think there are undoubtedly conditions which obtain in these overflowed portions which would enable some of those germs lying in the sediment of the overflowed banks to be returned to the stream.

2657 Those conditions would obtain in regard to all the dams along the Illinois river. There would be at times a sedimentation of removal from the flowing stream. They would become deposited upon the bed and following would come the scouring velocities and pick up and move them on. During those times there would be a dying out among the germs. I should not expect that the current at Lake Peoria would exceed two miles an hour under ordinary high stage conditions. Assuming that the current at Lake Peoria was six-tenths of a mile per hour, that velocity would not make a complete removal. There would be disturbances probably, boats and wind actions and such things, which would make a considerable removal of sediment, but not complete. I do not imagine that there are a great many boats that run up the Illinois river from Peoria. On an average when this water gets to Peoria, after passing the dams above Peoria and the lakes above Peoria, considerable elimination of its pollution and infection is accomplished. I presume ordinarily that this is true, but there are times when I think it is not so.

2660 I have not analyzed the sewage that comes from the glucose factory at Peoria. I know that the volume of sewage that is emptied into the Missouri river from the factories and distilleries at Peoria cannot be a very material one, for in examining the analytical evidence I have been unable to detect that that is a controlling—or I might say, a general or dominating factor, taking this entire proposition of the disposal of the Chicago sewage as it comes down through the Illinois river. I should say that the amount of sewage pollution in the Mississippi river at the Chain of Rocks, considering that water in its raw condition, is such that it would not be thoroughly safe. I would ascertain that fact with reference to the amount of pollution entering the streams above. I think it is very essential for any sanitary engineer or expert to ascertain the amount of pollution entering the streams above and it would be a very reckless proposition for any one to make a definite statement in the absence of such information. A sanitary engineer can ascertain from the water itself whether it is safe and usable or dangerous water, through the assistance of tests made for the presence of intestinal bacteria, which is colon bacillus.

2662 There are observers in Switzerland who made examinations of running streams with positive result showing the presence of typhoid germs in the sediment of Lake Geneva and I think also Lake Zurich.

2663 I consider that it is a very clean-cut demonstrated fact that typhoid germs may, do, and have continued to live in the sediment of running waters. I should say for a month or more, possibly in cases for years. I think that the conditions existing in the moist soil in many rural places in this country where typhoid fever prevails from time to time, are proof that typhoid fever germs in the presence of moisture can live for such a term. If that were not so, then there would be an elimination absolutely, of typhoid fever through the rural districts of this and all other countries. My common knowledge of existing conditions in many country towns satisfies me, beyond all doubt, that those germs have lived for at least a year. In a great many

instances, my common knowledge is superior to scientific demonstration.

2665 I think those germs live several years. I will not go into details beyond that. I think unquestionably they live several years. I think I am safe in stating that Prof. Sedgewick holds that a typhoid germ will live three years. I do not recall any one who has exploited that longevity for a typhoid bacillus in any work. I think that a prodigiosus bacillus was found in the Ohio river at Cincinnati on one occasion in the course of over a year's investigation, involving practically daily examinations of the waters of that river.

2666 Some typhoid germs, out of a large number put in water, I have no doubt, will live a year.

Q. If a typhoid germ should be deposited in Lake Itasca, from the excreta of an Indian up in that neighborhood, and that the typhoid germ floating down the Mississippi should enter the intake at New Orleans, and get into the system of a creole, would that creole be likely to take typhoid fever?

A. I think there is a decided possibility in that direction, and if there were enough of those individual instances, of one germ coming down from Lake Itasca to the New Orleans intake, there would surely trouble result to the person drinking that water in its raw condition, and in which were present germs coming from Lake Itasca. ?

RE-DIRECT EXAMINATION by General Crow.

Considerable typhoid fever prevails in the city of Louisville. The water supply for that city is drawn from the river and passes through settling basins holding five or six days' supply and in which sedimentation takes place.

2667 The sewage coming into the Ohio river is almost entirely confined to points at and above Cincinnati, which is distant about 150 miles by river. At times of low flow it would take those germs to pass from Cincinnati to the taps of the citizens of Louisville more than one month. I consider that is a very reliable demonstration that typhoid fever germs are not absolutely removed from sewage polluted waters in which that

pollution takes place, one month before the water is used. At Covington, Ky., the source of the water supply is the Ohio. There are provided sedimentation basins holding approximately thirty days' supply. It has been found that year after year the citizens of Covington using the Ohio river water coming from those basins are not protected from typhoid fever. I consider that there is no room for doubt but that a portion of the pollution existing in the Ohio river at Cincinnati is due to the sewage coming from cities and towns located in Allegheny County, Pa., between 450 and 500 miles away. I will further say that in my judgment were all sewage pollution of the Ohio river and its tributaries between Pittsburg and Cincinnati eliminated, I consider that the Pittsburg sewage would unquestionably make its influence felt in the hygienic character of the river water at Cincinnati (a distance of between 450 and 500 miles.)

2668 (Witness reads from report of the Chief of Engineers of the United States army in regard to the Illinois river, as follows):

"Channels dredged twenty years ago are but little deteriorated, and it is surprising to find that there has been no deterioration in depth in the pools created by the Henry and Copperas creek dams after from fifteen to twenty-eight years' use."

"The dams (meaning in the Illinois river) have no appreciable effect above mid-stage of the river when currents are the strongest, so that all lighter sediment is swept away as well now as before constructing the dams. That there has been no appreciable change felt in the pools of the Illinois river is a fact that has been so often remarked upon by steamboat men and persons interested in the use of the river since the construction of the first dam at Henry, thirty years ago."

JUDGE JOHNS: I move to strike out portions of the answer which are read from reports.

In my judgment, no great amount of sediment accumu-

lates and remains upon the bed of the stream of the Illinois river for any great length of time.

2669 RE-CROSS EXAMINATION by Judge Johns:

(Witness is examined as to the towns on the Ohio river near Louisville and Cincinnati, and the tributaries of that river entering said river between those points.)

2671 If there was constant accumulation and no scouring out of material that might be deposited on the bed of the Illinois or any other river, the result would be that there would not be any bed there.

WILLIAM H. GETZ, recalled and examined in chief by General Crow:

The table I have here is the same one I presented before, showing the percentage of mixtures of the Mississippi and Missouri rivers at the intake of the St. Louis waterworks. I have re-checked all the calculations and think there is no reason to doubt that that table is correct now as made from examinations and analyses of the water. The difference of amounts of total solids in the Mississippi river and in the Missouri river, at the points where these samples are taken, is found, and also the difference between the total solids at the intake and those at Hartford on the Mississippi river. In this manner the per cent of Mississippi river water is obtained.

The percentage of Missouri river water for instance would be the total difference divided into the difference between the intake and Hartford. (Witness states method of making the calculation of percentages from the table.)

(Table introduced in evidence.)

2679 (Section 2 of table shows calculations based upon daily estimation of total solids.)

2688 HIRAM R. MILLS, examined in chief by Attorney General Crow:

Am physician and reside at Soldiers' Home, Grand Rapids, Mich. Have been practicing medicine 35 years. Resided nearly all the time at Port Huron, Michigan. Left Port Huron on

the 25th of April, 1903. Was practicing physician in Port Huron in 1889, '90, '91, '92. Port Huron is on the St. Clair river and the Black river divides Port Huron into two parts and empties into the St. Clair river. There is not a great deal of difference as to the size of the town on either side of the St. Clair river.

2689 The present population of Port Huron is about 21,000. In 1890, '91, '92 it was probably 15,000 or 16,000. A large portion of Port Huron was sewered in 1890, '91, '92 on both sides of the river. The natural drainage for the greater part of the town is into Black river. There has been typhoid fever there off and on every year since I have been there, more or less. I have been there 33 years in December next. In 1891 there were four cases I looked up.

2690 They were under my personal knowledge. There were 4 in 1890 and 4 in 1891. The sewers of Port Huron empty into the Black river almost entirely. They have been emptying in there for a long time.

2691 The river was dredged from the mouth of Black river to the Fiber works in 1891, '92.

CROSS-EXAMINATION by Judge Johns:

There was a board of health in 1891 and '92 but it was not in very active running order. They did not have any statistics of deaths and causes of deaths at that time. The deaths and births were collected by the supervisors twice a year. A record was kept, but I do not know what became of them. As a matter of fact I suppose they were kept—I know that was the law. They had blanks furnished by the State and there was some disposition made of those blanks. There ought to be a copy in the County Clerk's office.

2692 The first case in 1890 was that of Otis Scott, corner Broad and Ontario streets. I attended him personally and he lived. I understood that the house at the time was connected with the sewers but I could not say positively that it was. I told the nurse what to do with the dejecta. She was to use disinfectants and put it into the closet. I think their

closet was connected with the sewer. I ordered that before it was put into the sewer it should be disinfected. I told them to use carbolic acid or copperas and sometimes to put in boiling hot water.

2693 The second one was Mrs. Bunce, on Lepear avenue, near 9th st. That was in October, 1890. There was a sewer on Lepear avenue, but I do not know whether their house was connected or not. I always give instructions for the disinfecting of the dejecta. I could not say positively whether the dejecta went into the sewer or not. The next in 1890 was Fred Gooding, Ontario street, near Pine Grove ave. I think that house was connected with the sewer. I am not sure about that either.

2694 I always gave orders to have the dejecta disinfected. I do not know whether it was or not in that case. I could not say positively whether the dejecta from that patient—whether disinfected or not—went into the river.

The next in '90 was Massmore on Lepear ave. That was connected with the sewer. I gave the usual orders to have the dejecta disinfected. I suppose it was done but I don't know. I don't know whether the dejecta—whether disinfected or not—went into the river, but I suppose it did. In 1891 was Mrs. John Folkers, 1209 Miller st. There was no sewer on that street for that house.

2694 The dejecta was thrown into the closet and the closet drained into a little stream there—Indian creek, or the stream that ran down into Indian creek through the

2695 clay. It was one of those surface vaults that might be washed out by flood or something of that kind. At any time there was a heavy rain, there would be a certain amount of sewage from this vault which would go into Indian creek and that went into Black river. I gave the usual orders to have the sewage disinfected but do not think it was done because it was that class of people that would not be apt to do it if you did tell them, while I have no positive knowledge in regard to it.

696 I have no knowledge positively as to whether the dejecta of that patient—disinfected or not—went into he vault or outhouse; that is a surmise.

In October '91 is another of the same family, living right n the bank of the Black river. This house was not connected vith the sewer. The outhouse was practically on the dock over he edge of the river. I gave orders to have the dejecta disinected but do not know whether it was done. Another in 1891 vas John McFadden, Court street. I think it was connected

697 with the sewer in 1891, but I don't know as I never traced it. Gave the usual orders to have the dejecta disinfected but do not know whether it was done. There was a waterworks in Port Huron in 1890 and 1891. The water supply was aken from the St. Clair river above the mouth of Black river. think all of these cases in 1890 received their water supply in he houses from the public waterworks of Port Huron. The vater of Port Huron was not filtered. It came direct from the St. Clair river.

698 It is counted one of the best water supplies of the world, but there was contamination there—that is where we ot our fever from. The upper part of the city extended quite distance above the intake pipe and contaminated water was onstantly going down from the upper part of the city into the St. Clair river from the cases that occurred along the eastern lope of the city. This man Scott drank the water from the pubic water supply without filtering it. I am positive of that. I ttribute this case of typhoid fever to the contamination of the water supply of Port Huron.

699 Fred Gooding also received the water from the waterworks. He was the only one in the family having typhoid. know he drank water from the public supply. I know the Bunce family did not have any well—their water came from the ublic supply. It is a mere theory that these cases in 1890 and 891 were attributable to the water supply. It could not be lemonstrated. In 1891 the people sick with typhoid who re-

ceived their water from the public water supply were the Folkers on Miller street.

2700 The Fiber Works are about three-quarters of a mile from the mouth of Black river. No sewers of the city empty into the Black river above the Fiber Works. Dredging was done in the Black river up to the Fiber Works in 1891 and 1892. These cases were about equally divided on the north and south side of the city. The waterworks system extended on both sides of the city.

2701 99 per cent of the people in Port Huron or at least 90 per cent, use the public water supply. The dredging was started in 1891 in May, June or July, and there was some dredging done in 1892, probably the first part of the summer.

2702 This dredged material was taken and dumped over the shallow places, over the tunnel, or in the deep places, where the tunnel came near breaking through and that would be probably two-thirds of the way across from the American side, along the line of the tunnel under the St. Clair river.

2703 It would look as if the major part of this dredging matter was deposited over in Canadian water about 30 miles above Lake St. Clair. It may be about 35 or 40 miles by river. St. Clair river is a wide, rapidly flowing stream and St. Clair lake is, in places, very shallow. In fact, it is a shallow lake. The current is along the channel in the lake and there is something of a current there. It broadens out so that the current is very much reduced after it leaves the canal—it goes through the ship canal, you know. The ship canal connects the St. Clair river with the lake up at Star Island. On the south of

2704 the lake, after you go down the St. Clair river to Lake St. Clair, then through Lake St. Clair, is the Detroit river. St. Clair lake was dredged to make a channel but not the entire length. While the current is not so swift as in the St. Clair river, there is considerable current in Lake St. Clair. The Detroit river current is also swift. There is an enormous quantity of water that flows down the St. Clair river.

2705 The river is not subject to great floods. It only varies

in depth with the wind. It is a straight between Lake Huron and Lake Erie. It is about 65 miles from Port Huron to Detroit by river. The speed of the current in St. Clair river varies. At the foot of the lake, it is about six miles an hour and as you get down, it is probably about 3 miles an hour in the lake.

2706 The speed of the current of the Detroit river is not as strong and rapid as that of the St. Clair river. There is a considerable agricultural population on both sides of the St. Clair river, having its natural drainage into that river. There are a number of summer resorts and club houses on Lake St. Clair.

2707 It is a great resort—fishing, duck hunting, boating and clubs. Large numbers of people resort there during the fishing and hunting season. The number of resorters at Lake St. Clair and the St. Clair river in the summer would be in the thousands every day. These people might as well have had typhoid fever as anybody else.

2709 CROSS EXAMINATION by Mr. Todd.

2710 Among those 8 people having typhoid fever, two resulted fatally, Mrs. Bunce and Mr. McFadden.

2711 Most of the nurses were just their own people. For instance, Mrs. Bunce was attended by her daughter. I left directions with the nurses in all these cases for the disinfecting of the dejecta and how to attend the patient, and I found that in matters which came directly under my observation, these nurses carried out my instructions and there is no reason to believe they did not. The only thing is, I know that sometimes they get careless about those things, but that is outside of my knowledge. As I said a minute ago, we had our water contaminated from sources above the intake pipe. Exclusive of the sewage of Port Huron, there was what is called McNeil creek which drained quite a territory in that part of the city.

2712 There was nothing outside the city draining into the river.. The theory our medical society has had there always, has been that we had contaminated water or contaminated

milk. As to what brought the typhoid fever in this particular locality was not discovered in this particular instance.

2713 It might have come into Port Huron by rail, but there are no cities above Port Huron and it must have come just from the town itself—contamination of the water there.

RE-DIRECT-EXAMINATION by General Crow.

Am not an expert on stream flows. What I said about the rapidity of the current of Lake St. Clair and St. Clair river is guess-work. Typhoid fever has existed in Port Huron for 33 years to my knowledge, that being the time I was there. The disinfectants that are applied to stools of typhoid patients do not always destroy all the typhoid bacilli entirely. If the disinfectants were used in the manner in which I prescribed them to be used, it did kill them—it ought to destroy the germs. I do not know that it was used in that method. My experience as a physician leads me to believe that they did it with a great deal of carelessness.

2715 CHARLES B. STOCKWELL, examined in chief by General Crow.

Am physician and surgeon. Reside at Port Huron, Michigan, have lived there 51 years and practiced medicine 23 years. Was practicing in Port Huron in 1892. There was typhoid fever cases in Port Huron that year. From personal knowledge I have record of three, in February, March and April—one case extended into May. In one case I know there was direct connection with the river by private sewer and in another there was connection through one of the sewers which emptied near the waterworks. In another case, the house was located on the border of Indian creek which emptied into the Black river—whether there was a sewer there or not, I cannot tell.

CROSS EXAMINATION by Judge Johns.

2716 This case in which the sewage went directly into the Black river by private sewer was attended by me personally. The sewage was not disinfected that I remember. I did not give instructions to have it disinfected. That was my practice or custom. The case having indirectly a connection by

# ABSTRACT TABLE NO. 1.

The following table shows the results of the bacteriological investigation made by Dr. Ravold for what is termed the "First Period." This is before the canal was opened. In his testimony it is referred to as the period from Aug. 10, 1899, to Jan. 23, 1900. Dr. Ravold testifies, however, on Record 85, that between September, 1899, and Jan. 23, 1900, there were no bacteriological investigations carried on by him to determine the presence of coli communis in the water. Reference is made at the head of the table to the page of record where the testimony will be found. If the testimony extends to some other page of the record, such page is indicated directly above the number of bacteria. A plus sign indicates the presence of bacilli coli communis; a minus sign denotes the fact that bacteria was found. Where there is no sign after the number of bacteria, the witness has not testified that the same was examined for coli.

| 1899 | | Mississippi River, just above the intake. (80) | Intake, as water flowed in. (80) | Uptake. (80) | Illinois River, Wheeler's Ferry, 3 miles above mouth. (83) | Illinois River, 5 miles above mouth. (Brick House Club.) (83) | Illinois River, 7 miles above Grafton—6-mile Island. (83) | Mississippi River, opposite Grafton (83) | Mississippi River, 4 miles above Grafton. (83) | Mississippi River, 6 miles above Grafton. (83) | Mississippi River, Chain of Rocks (83) | Mississippi River, Madison Landing (above mouth of Missouri River.) (83) | Missouri River, just above the mouth. (83) | Mississippi River, 1½ miles below Alton. (83) | Mississippi River, 1 mile above Alton. | Mississippi River, opposite Grafton | Mississippi River, 1 mile below Grafton | Illinois River, just above Grafton. (83) | Mississippi River, 2 miles above mouth of Missouri. (84) | Illinois River, 1½ miles above Grafton. (Rec. 84) | Mississippi River, 1 mile above Grafton. (Rec. 84) | Missouri River, opposite Clifton. (Rec. 85) | Mississippi River, ½ mile below Portage (Rec. 85) | Intake, Illinois shore, toward Illinois shore. (80) |
|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|---|
| August | 10 | 275 | 500 | 600 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 11 | ..... | ..... | 650 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 12 | ..... | ..... | 650 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 14 | ..... | ..... | 650 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 15 | ..... | ..... | 1,500 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 17 | ..... | ..... | 750 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 18 | ..... | ..... | 650 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 19 | ..... | ..... | 400 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 21 | ..... | 375 | 325 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 22 | ..... | 950 | 150 | ..... | ..... | ..... | ..... | ..... | .... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 23 | ..... | 550 | 1,300 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 24 | ..... | ..... | 475 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 25 | ..... | ..... | 400 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 26 | ..... | ..... | 275 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 28 | ..... | ..... | 275 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 29 | ..... | ..... | 170 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 30 | 275 | ..... | 300 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| September | 4 | ..... | ..... | 300 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 5 | ..... | ..... | 270 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 6 | ..... | ..... | ..... | 130 | 170 | 160 | 190 | 550 | 276 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 9 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 160 | 210 | 180 | 190 | 240 | 160 | 130 | 90 | .... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 11 | ..... | ..... | 300 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 12 | 650 | .... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 13 | 1,500 | .... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 15 | 2,300 | .... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |
| | 16 | 1,700 | .... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 1.700 | 800 | 2,600 | Rec. 84 800 | Rec. 84 700 | .... | .... | .... | 700 | ..... | ..... | ..... | ..... | ..... | ..... |
| | 20 | 1,200 | .... | ..... | Rec. 84 400+ | Rec. 84 425+ | .... | ..... | 500+ | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 450+ | 500— | ..... | ..... | ..... | ..... |
| | 21 | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | Rec. 84 3,600+ | 750— | Rec. 84 5,600+ | 750+ | ..... | ..... | ..... | ..... | ..... | ..... | ..... | 730+ | 600— | ..... | ..... |
| | 25 | 3,600 | .... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... | ..... |

## ABSTRACT TABLE NO. 1A.

Table showing result of bacteriological examination of Lake Michi-n water, taken from places indicated, which are intakes for the ter supply of Chicago. Based on testimony of Dr. Ravold, pp. 95-6 Record.

This is second period of investigation made by Dr. Ravold, running om Jan. 23, 1900, to Oct. 10, 1900.

| | | Four-mile Crib. Rec. 96. | Carter Harrison Crib. Rec. 94 | Ten miles from shore. Rec. 94 | Lake View Crib. Rec. 96. | Two-mile Crib. Rec. 96. | Three-mile Crib. Rec. 96. | Sixty-eighth Street Crib. Rec. 95-96. | Four-mile Crib. Rec. 96. |
|---|---|---|---|---|---|---|---|---|---|
| 1900 | | | | | | | | | |
| y | 23 | 1,600+ | | | | | | | |
| | 30 | | 12,300+ | | | | | | |
| gust | 9 | | Rec. 95 | 16,300+ | | | | | |
| | 31 | | 21,400+ | | | | | | |
| tember | 7 | | | | 5,200— | | | | |
| | 15 | | | | | 909,700+ | 111,500+ | | |
| | 22 | | | | | 61,000— | | 44,000— | |
| | 28 | | | | 3,100+ | 11,300— | | | |
| mber | 11 | | | | | 1,000— | | | |
| | 19 | | | | | 4,400+ | 1,100— | | |
| | 26 | | | | | | | 157,500— | 90,000— |
| vember | 9 | | | | | | | 3,300— | 2,900— |

[See Rec. p. 96 for species of bacteria found, all of which are harmless except bacillus coli mmunis, and that only when injected beneath the skin.]

FOLD OUT IS TOO LARGE TO BE FILMED

sewerage with the St. Clair river was at the southern border of the park, within 200 feet of the St. Clair river. There was a public sewer leading from that house to the St. Clair river below the intake. The mouth of the sewer in the St. Clair river would be half a mile above the mouth of the Black river. The current of the St. Clair river would carry that sewage, if deposited in the sewer, past the mouth of the Black river. There were experiments carried on to find out whether any of that sewage could get into the water supply. The other case was on Court street, but that was my father's case—he is now dead. I do not know where the discharges from that patient were deposited or whether they were disinfected or not. Another case was 200 ft. from Black river, just above the 7th street bridge, that is below the Fiber Works. It is connected by private sewer to the Black river.

2718 I do not think the discharges of that patient were disinfected. That would be Feb. 6, 1892.

CROSS EXAMINATION By Mr. Todd.

2719 Those were the only cases I had in February, March and April, 1892. I think there were other cases I have had but those were all I was asked to look up. Typhoid fever was prevalent at Port Huron at this time.

2720 OLIVER STEWART. Examined in chief by General Crow.

Am physician. Reside at Port Huron, Michigan. Have lived there 16 years. Practiced medicine there in 1889, 1890 and 1891. In 1889 I had five typhoid cases—in August, 3 cases; September, one case, and one that ran between October and November. In 1890 I had five cases, four in one house in September, and I had one case on 9th street in September. In 1891 I had four cases—one in September that ran into October and in October I had three other cases, one of them being a tramp at the hospital.

2721 I am not sure but I believe one of the houses in which these patients were located had sewer connection. It was



Vol 2

over at the end of Pleasant street, in 1891. I believe the hospital was connected with a sewer at that time. There were about 20 physicians practicing in Port Huron during that period.

2722 I know as a matter of fact that there were other cases of typhoid in Port Huron besides those I attended.

CROSS EXAMINATION By Judge Johns.

In 1899, one case was that of a colored woman, very poor. I don't know whether they had sewer connection with that house. The house of Gilbert Rogers—another case—I am pretty sure was not connected with a sewer. It was a standing thing for me to leave material to disinfect the discharges.

2724 Those four cases that I had in one family were three boys and one girl. I think the instructions as to disinfecting the dejecta were carried out in those cases. In 1891, in the case of the boy on Miller street, I think the instructions were carried out.

2725 I don't believe the sewage discharges were disinfected at the hospital.

CROSS EXAMINATION By Mr. Todd.

2728 Among those cases that I have given an account of, I believe there are only two from which the excreta emptied into the sewers.

2729 FRANK F. ROGERS Examined in chief by General Crow.

Am a civil engineer. Live at Port Huron, Michigan. Have lived there since June, 1890. Been civil engineer for twenty years.

2730 Black river is a very sluggish stream in most seasons of the year, having no perceptible current, excepting during the Spring freshets and excessive rainfall. (Explains the topographical situation with reference to the location of Port Huron on the Black river and St. Clair river.) The bottom of Black river—the native soil—is sand and clay, having a little gravel and a good deal of soil is washed into it from above. The intake of the waterworks of Port Huron in 1890, 1891 and

1892 was on the west side of St. Clair river a little over a mile north of the mouth of Black river.

2731 The river flows in a southerly direction. The intake is located near the shore. There were no city sewers up the river above the intake excepting what we call the Grant Locomotive Shops, which discharge sewage of a considerable population at times. The city was always given to understand that it was not used as a regular sewer for feces, but I know it was used for urine. It was perhaps half a mile above the waterworks. There would only be a little portion of the territory north of the intake that would naturally drain by washings of rain into the river. The banks are quite high, without any decided slope to the St. Clair river from the waterworks north, until we get up to where a creek known as McNeil creek, used to enter St. Clair river and then the natural flow is along that creek-bed into the river.

2732 In 1890, 1891 and 1892 there were deposits of sewage from Port Huron into the Black river in front of and adjacent to the wharves and docks there. That was removed by dredging in 1892 partly. I think there was a little dredging done in the fall of 1891. The principal dredging was done in 1892. The object was to secure shipping facilities along the stream and also on account of making a winter harbor for vessels. The channel was deepened at that time from the neighborhood of 12 to 16 feet and to the width of 100 feet in the central portion of the river. The material was dumped into St. Clair river. In 1891 there were about 10 miles of sewers in Port Huron and about two miles were added in 1892. All these sewers emptied into Black river.

2733 CROSS-EXAMINATION by Judge Johns:

The Fiber works or Iron Bridge, is approximately a mile and three-quarters from the mouth of Black river. The Government dredged to Washington avenue, which is the north boundary of the Fiber works property, and the channel was 100 feet wide to Suffern street and 50 feet wide from there above. That took it through the built up portion of the city.

At that time all of the sewers emptied into Black river at and below Suffern street. There were six large sewers, not counting some private sewers that I haven't any record of. In 1890 less than one-fourth of the total inhabitants were accomodated with sewers.

2734 The larger part of that was from the better residence portion and the business portion of town. In 1892 the dredging commenced in the Black river in April and continued through the summer season. The dredged material was loaded on to scows and taken out into the river and dumped from the bottom of the scows.

2735 The ordinary lake boats of today or of 1890 could not go very far up the Black river, without this dredging. It is a very sluggish stream. The Fiber works is the principal manufactory on the banks of the river. It deposited the water that came from their process of manufacturing paper cloth into the river. It is dirty and discharged in quite large quantities. There are such fish as German carp and cat fish in the Black river. The ordinary lake fish do not live in it. They do not seem to like the waters.

2736 (Witness explains the drainage areas and the sewage system of Port Huron in 1890 and 1891.)

2739 I saw the material that was dredged when it was passing through the bridges. It was earthy material and such refuse as had accumulated in the river above it.

2740 Like any other river working under a good current, I suppose that the Black river scours the same as any other stream, so that the ordinary sewage deposits in the Black river in times of flood would be washed out to some extent.

CROSS-EXAMINATION by Mr. Todd:

I never made any soundings of the river to ascertain how much of the deposit above its natural bed was created by the sewage discharged into the Black river. I have no definite idea or opinion upon the subject.

2742 The water of the Black river is a dark colored water. The source of the Black river is in mucky swamps.

There is a town of a thousand or two thousand above Port Huron on the Black river about 25 miles up.

2743 The last sewer above the mouth of the river was at Suffern street, a little over a mile from the mouth.

2744 MR. TODD: I move to exclude the evidence of Charles B. Stockwell, Hiram R. Mills, Oliver Stewart and Frank F. Rogers, for the reason that the evidence is incompetent, irrelevant and immaterial.

2745 E. J. HAYNES, examined in chief by General Crow: Live at Detroit. Am United States Inspector at United States Engineer's office, Detroit. I have been in this same line for 14 years, first as laborer and since 1891 as Inspector. According to civil service rules, an inspector is a man who takes charge of dredging rivers or lakes. He keeps track of the amount of material dug, the positions it is dug in, and makes a weekly or monthly report to the United States Engineers' office in charge of the work. There was dredging done in the fall of '91 and the spring of '92 in the Black river and in front of Port Huron, Michigan.

2746 I was connected with that work. We began that work about the 27th of November. The character of the work we did there at that time was deepening the river somewhere between the mouth and 10th street and the material dredged was taken down to the St. Clair river and dumped, as near as possible over the St. Clair tunnel. There was work done in the spring of 1892 at Port Huron in the Black river.

2747 I could not say just how long it lasted. I went there about the middle of April. I was there for something like two or three months. I had charge of the work as inspector during May of 1892. The material was dredged out of the Black river between Military and 10th streets in Port Huron, and taken to the same place in the St. Clair river. 5,300 cubic yards were taken out in April, 1892. It was done by contract under the supervision of the Government employes.

CROSS-EXAMINATION by Judge Johns:

I first drew my pay as inspector in the spring of 1891. I was not the sole inspector of the work in 1891.

2749 There was dredging done in the spring of 1892 above Military street. In May, 1892, the river was dredged in front of what is called Haynes' Lumber Dock about two blocks above 10th st. The cutting in some places, would be 4 feet, not over that, and the average for the entire

2750 distance up to 10th street, was about 2 feet. This dredged material consisted of some sediment and very little sand and blue clay. Not over one-third would be blue clay. The rest of the dredging would be mixed entirely with a black muck, it is a wash from the marshes above, and I shouldn't think—probably one-sixth of the entire remaining material would be sand. The sediment which is in the bottom of the Black river is partly the wash from the swamps and marshes in which that river has its origin.

2751 There was another contract for the deepening of what they called the Middle Grounds, gravel washed from the rapids of the St. Clair river. These Middle Grounds were directly below the mouth of the Black river on the American side.

2752 There were 5,300 yards taken out of the Black river in 1892. I obtained those figures from the U. S. Engineer's office in Detroit, last Tuesday. I investigated this record at the request of Mr. Gardner S. Williams.

2753 He communicated with me from Ithaca, New York, about the 16th of June. The St. Clair river is about three-quarters of a mile wide at Port Huron. The current is quite swift towards the Canadian shore and towards the American shore there is an eddy that causes gravel to settle on the American side. The dumping was done on the Canadian side. The dumping was done by scow loads and not in one body. The same is true of work done in 1892.

2754 These 5,300 yards were obtained in 1892 from the Black river between 10th and Military streets. 10th street is something over half a mile from the mouth of Black river.

There are ten streets. This dredged material was de-
2755 posited along the line of this tunnel for a distance of about a quarter of a mile.

CROSS-EXAMINATIONS by Mr. Todd:

I don't know in what months the dredging was done in 1891. I know there was some done in November.

2756 I do not know whether there was any done in December or January, I believe the season was closed in November, 1891. If that statement is true there was no dredging done in December, 1891, and January, February and March up to the middle of April, 1892. The material that was dredged gave off rather an offensive odor at all times. There was a sediment from all the causes I suppose that ordinarily occur in such a creek, where the sewage and such things were dumped into the river. During the summer months there was no current. In the spring there was a freshet which took the ice and everything out. The character of the soil, excavated between 6th street and the river was the same as that found above 6th street, as I remember. I did not observe any difference in the character of the dredging.

2757 The same characteristics prevailed from the mouth of the river up above the point where we ceased to dredge. This dredging was done immediately in front of the city of Port Huron.

WILLIAM C. TEICHMANN, recalled for further direct examination by Attorney General Crow:

These are 19 charts which were prepared under my direction and supervision by Mr. Alexander Miller and Mr. William H. Getz. They are the ones referred to in my testimony as charts No. 1, 2 and 3, and so on, up to 19. They are made from the analyses made under my direction in this case. They are made entirely from analytical data which I collected from the analyses of samples of water made in the City Chemist's office during the years 1900 and 1901.

2758 (Said charts received in evidence, marked Complainant's exhibits No. 52 to 70 inclusive.)

WILLIAM T. SEDGWICK recalled and examined in chief by General Crow:

When on the stand before, I testified as to the pollution of certain streams which I then named, which had come under my personal observation, which pollution was caused by sewage being discharged thereinto. I have investigated other streams and found the waters polluted. I refer to the pollution of the Potomac river and the effects of this pollution on the typhoid fever conditions in Washington, D. C.

(Witness refers to examination of typhoid records and correspondence had with physicians since the time he testified in this case in regard to the epidemic of Cumberland, Md.)

2759 JUDGE JOHNS: I object to any recitation of facts learned by witness from other source than his own personal observation, etc., and move to strike out the testimony.

MR. TODD: The Sanitary District joins in the same objection.

I ascertained that there was an epidemic of typhoid in 1889 and 1890 in the city of Cumberland, Md. There appeared to have been in January, 1890, 18 deaths; in February, 27; March, 39; April, 8; and May, 5. There was also one death in December, but it was that of an imported case. That was December, 1889.

2760 There was, all told, in the epidemic in Cumberland, 98 deaths from typhoid and although it has been repeatedly stated in the sanitary discussions and pamphlets that there were 485 reported cases of typhoid fever in Cumberland, the number of deaths indicates that there must have been actually nearly double that number. An effect of this epidemic appears to have become marked in Washington in 1890 and to have extended as follows: March, 19 deaths; April, 11; May, 13; June, 33; July, 36; August, 28, and after August, no effect of the epidemic can be traced in the deaths from typhoid fever in Washington. I regard it as a most instructive example of the

transmission of typhoid germs in a polluted stream over a long distance, because Cumberland is about 175 miles from Washington by river, and because the river is of such character as to offer a good example of a stream neither very swift nor very slow, but having occasional areas of what might be called slack water; these succeeded by steeper portions, and therefore affording good opportunities for a certain amount of so-called self-purification en route.

2761 (Offers a copy of Dr. Kober's plate showing the unsanitary conditions at Cumberland.) Between October 4, 1889 and March 18, 1890, the sedimentation basin in Washington was out of service, so that the water was delivered to the citizens of Washington without purification of any kind, a fact which no doubt added to the severity of the outbreak in Washington.

MR. TODD: I move to strike out the answer for the same reasons that are stated in the last objection made.

JUDGE JOHNS: The State of Illinois joins in the same motion.

In Senate Document No. 94, 55th Congress, Second Session, Capt. Gaillard of U. S. Engineers, gives the rate of flow from Cumberland to Washington, of the Potomac river to be 4 to 7 days and one of the officials of the U. S. Geological Survey gives it as 2 to 4 days.

2763 (Motion to strike o t answer and all recitations and conclusions cited by witness in regard to other experts.)

The population of Cumberland at that time is said to have been 12,000. It is nearly 20,000 today. The epidemic in Cumberland is supposed to have been caused, and in my judgment, was caused by an infection of their own water supply by a case of typhoid fever just above the intake of their waterworks. The source of their water supply is the same stream as that of the city of Washington—the Potomac river.

2764 The number of deaths in Washington during this epidemic was 140, that would indicate 1,400 cases. The population of Washington at that time was 250,000. The prob-

lem of the water supply of Washington has been a matter of very grave concern to the citizens of that city. It has long been high in typhoid fever. It has been attributed, in my judgment, and with reason, in large part to the use of the polluted water of the Potomac river. It was recognized that the Potomac is a polluted stream, although there are very few sewered towns upon it, but there are these overhanging privies and the like, and it is anything but a good supply. Steps, however, are being taken at the present time to adequately purify it. They are going to use partly the slow sand filters and when the water is very turbid and clayey, the rapid mechanical filters.

2765 That is the Alton method, so they will have a combination of the two methods of filtration. The Thames in the United Kingdom is 209 miles long, and this epidemic seems to confirm in a very remarkable way that statement of the Rivers Pollution Commission of Great Britain, to which I have referred in my previous testimony, where they said that there was no river in the world that was long enough to purify itself of any sewage introduced into it, even at its source. From my knowledge of the situation and of the conditions that prevailed in 1889 and 1890 in Cumberland and Washington on the Potomac river, this excess in typhoid deaths in Washington is directly traceable to the epidemic occurring shortly before and during a portion of the same period in Cumberland.

2767 CROSS EXAMINATION by Judge Johns.

I made examination of the excess of typhoid fever in Washington immediately after I left St. Louis on my last visit and about the first of June and after I had finished my testimony here in May. I was then in the employ of the State of Missouri and was instructed by the Attorney General to make this investigation. I am still in the employ of the State of Missouri as an expert in this case and expect to be until further notice. I understand that I am acting for and in behalf of the State of Missouri, in an advisory capacity in this lawsuit as as expert.

2768 Washington City receives its water supply at a point called Great Falls, 14 miles above Washington. That information I derived from a report from which I am now refreshing my memory. I understand the tide is felt above Washington, but salt water does not run up above Washington.

2769 At the time of this epidemic I suppose the water was pumped virtually from the Potomac river into the mains of the city of Washington. That is stated in a letter of Capt. Gaillard, U. S. Engineer, dated February 24, 1898, addressed to Dr. Kober the well known sanitary expert who first studied the Cumberland epidemic and who first pointed out its probable connection with Washington. So far as I know, no one has studied it thoroughly except Dr. Kober, and if I may be permitted to say so—myself.

It was Dr. Kinyoun who had grave apprehensions as to Asiatic cholera when it was discovered that there was a case in Cumberland.

2770 He is the only one I know who had such anxiety. I did not talk with Dr. Kinyoun myself. My information as to his grave anxiety arises from reading something that he got into print.

2771 Whether any committee of Congress actually investigated the typhoid epidemic in Cumberland I am not prepared to state. There were 485 cases reported in Cumberland.

2772 That rests upon the authority of Dr. W. W. Wiley of Cumberland. I believe there were 485 reported cases but I also believe that there must have been upwards of about one thousand cases, judging by the deaths.

2773 The drainage area above the intake figures 11,043 square miles. Col. Miller gives the population as 44½ to the

2774 square mile. There is a considerable number of towns above Washington and below Cumberland. There are towns upon the branches of the Potomac river above Cumberland. The valley of the Potomac river is a very rich and fertile

country and is thickly populated and has upon it a large amount of domestic animals.

2775 In '89 there was no typhoid fever in any of these towns, save Cumberland, so far as I have been able to learn. I was in Cumberland half a day, arrived at noon and left at night. Talked with Dr. Wiley, Dr. Johnston and Dr. Speers.

2776 There were no health records in the office for any period prior to 1900.

2777 Having learned from the reports of conferences that there was considerable typhoid fever at Cumberland at one time and subsequently a remarkable increase of typhoid fever in Washington, and not knowing as to typhoid fever any place else, I conclude that the typhoid fever in Washington is attributable to Cumberland. I cannot tell why the cases in January in Cumberland did not show any effect in Washington, in February.

2778 In June '89 there was a freshet in the Potomac river, according to the statement of Capt. Gaillard. I do not know whether there was any flood in 1890. I believe that the typhoid fever which occurred in Cumberland in January, '90, contributed to the typhoid fever in Washington in March of the same year.

2779 We have good reason to believe that germs of that disease were deposited in the Potomac water at Cumberland and we know that this water travels down the river and is in part at least, used for drinking purposes by the people of Washington. We find an otherwise inexplicable excess in Washington at a time following, when such increase would reasonably be unexpected.

Q. All the water in the Potomac river at Cumberland had flowed past the city of Washington in the Potomac long before this epidemic or increase of typhoid fever in Washington, that is to say, the water infected, if it was infected, by typhoid fever in January at Cumberland, had flowed past the city of Wash-

ington a very considerable time before allowing for the period of incubation, had it not?

A. I should suppose that it must have in a large part. Perhaps entirely.

Q. Then, if the typhoid fever in Cumberland in January contributed to the typhoid fever in Washington in March, the germs must have been deposited somewhere in the meantime?

A. That seemed to me a very decidedly suggestive fact, but I think we should bear in mind that in January it is possible that the stream was tightly frozen and that sedimentation took place to an unusual extent for a time, the so-called self-purification going on. I have no personal knowledge of the Potomac river being frozen between Cumberland and Washington. There is no way of determining as an actual fact, whether any typhoid fever germs were deposited in any of the sluggish places of the Potomac river.

2780 Nor whether they were washed out so as to contribute to the typhoid fever in Washington in March. We can only infer from the end result what may have happened and the belief that typhoid fever in Cumberland was the cause of typhoid fever in Washington is based on the theory that typhoid fever germs will live in water and are transported by water and retain their virulence and that theory in this case must be applied to a distance of 160 to 165 miles.

CROSS EXAMINATION By Mr. Todd.

There was no regular system of sewers in Cumberland in '90, but there were short, private sewers and according to the best information I can obtain, privies overhanging streams then as they do now and draining into the runs which contribute to the river.

2781 I should suppose that one-third to one-half of the population reside immediately upon the banks of the Potomac river and the two little runs.

2782 I have no information as to the number of typhoid deaths that occurred in houses where the privies overhang the stream, or that occurred in houses that used private vaults.

2783 I have no information as to how often the privy vaults of Cumberland were cleaned or renovated.

2786 If there should have been 15 or 20 cases of typhoid fever at Harper's Ferry, as to whether that could be attributed to account for the increase in Washington, would depend upon whether Harper's Ferry had had a similar outbreak before, and if so, what the effect of that had been on the typhoid rate in Washington.

2787 I made no inquiries of anybody except the health authorities of Washington and Cumberland.

2788 I made no investigation to ascertain the number of typhoids between Cumberland and Washington.

2789 ALLEN HAZEN Examined in chief by General Crow. I reside in New York city. Am a civil engineer.

2790 Have studied chemistry, particularly the chemistry of water supplies. (Witness states his qualifications as an expert.)

2792 Am engaged at Ithica now building a filter plant. There was a typhoid epidemic in the winter due to the use of the Six-mile Creek water. I built a filter plant at the State Lunatic Asylum, at Harrisburg, Penna., at West Superior, Wisconsin, at Watertown, N. Y. and at Yonkers. I advised the city government of Pittsburg, Penna. as to the character of their water supply. The water supply of Pittsburg was unsatisfactory because it was sewage polluted and caused typhoid fever among the users.

2793 Have advised in regard to filter plant at Providence, Rhode Island. The Pawtucket river above the intake is polluted by sewage and waste from mills and was unwholesome because of that. The desire for the purification of the water at Washington and the making of plans for filters in Washington, was because of the sewage pollution which that water received. I advised the city of Chester, Penna., in an action which it brought to compel the water company to furnish pure water. Principally the sewage of Philadelphia occasioned the impurity of the water at Chester.

2794 I have advised Trenton, New Jersey with reference to the quality of its water supply. The source of supply for that city is from the Delaware river. The principal reason for wishing to make other arrangements was the pollution by the city of Easton and other cities above. Was member of the Commission to investigate the waterworks of Toledo, Ohio. Those waters are polluted by the sewage of numerous cities and towns up the river. The Maumee river is the source of supply. Had engagement to examine waterworks and report on means for improving them at Grand Rapids, Michigan, Lancaster, Penna., and Millbury, Mass. I advised the town of Millbury in a suit which it brought against the city of Worcester, to compel it to purify its sewage so that it would not pollute the Blackstone river.

2795 Worcester had established a sewage purification plant as it had been required to do as a result of the action which Millbury brought against it. Prior to that time its purification plant was only partial. Since that time the court has compelled a greatly extended and improved character of the plant, so that the stream has been much more satisfactory than it had been prior to that time.

GENERAL HAMLIN: I move to strike out everything in that answer regarding the suits and complaints and results of suits at Millbury.

Was consulting engineer for the Ohio State Board of Health for a few years. I think in 1898 and 1899. Visited Chicago in 1891. I was very much interested in the water question and I met several officers and others interested in the matter and saw something of the waterworks and sewage disposal at that time. In a general way I became familiar with the conditions that then obtained. I did some work with Professor Sedgwick on the question of typhoid in Chicago.

2796 After that visit I secured additional data and worked them up with Prof. Sedgwick and wrote a paper jointly with him upon the typhoid fever in Chicago, which was published. That was with reference to the water supply, and was

in 1892. Later I made a report on the drinking water used in Jackson Park during the World's Fair period. I also wrote a paper jointly with Prof. Reynolds, who was then and I understand, is now Health Commissioner of Chicago, upon the water supply of Chicago. I have made maps showing the location of sewer outlets and water intakes for different periods. These maps were also arranged to show the typhoid death rates.

2797 Have observed the Chicago river and the canal at Joliet. I was at LaSalle in 1893 and examined the waterworks at that time. Saw the Illinois river and the canal. I made analyses of the Illinois and Michigan canal water at that time. I think my last visit to Chicago was January, 1902. I have looked at plans for various parts of the sewerage work in the city of Chicago. I went through part of the large sewer being built on 39th street. Have noticed the condition of the Chicago river before and since the opening of the canal. First visited the St. Louis waterworks in 1896. Was a member of the Commission to report on improvement of the water supply of St. Louis. Appointed in 1901 and reported early in 1902.

2798 Examined the waterworks system, pumping station, etc., etc. Went up as far as Grafton at the mouth of the Illinois river. Investigated sources of pollution above the intake tower upon the two rivers. Made tables of the populations of towns on the banks of the various tributaries and of their distances, from the best data I could get. In making these diagrams and tables we used the data of the Census office, and for the maps and distances, the Census report of 1880 on water power, was very useful. I used whatever Federal Government records were accessible to me. I got the record of typhoid deaths in St. Louis as reported at the Health office. I made no detailed investigation of the methods of securing and recording that data. At that time I studied the relation of Chicago sewage to St. Louis water supply. Since 1901 I have been familiar

2799 in a general way with the conditions in St. Louis. I have paid some attention to the record of typhoid fever

deaths in St. Louis since that date. (Objection and motion to strike out.)

Q. Mr. Hazen, I will ask you what has been the effect, if any, in your opinion, of the discharge of the waters of the Chicago drainage canal, carrying the sewage of the Chicago sanitary district, into the Des Plaines river under conditions existing since January 19, 1900, upon the water of the Mississippi river along the Missouri shore, and particularly as drawn from the intake tower of the waterworks at the Chain of Rocks, with reference to its use for drinking and domestic purposes?

A. I believe that the quality of the water is seriously damaged by this discharge.

2801 I am only familiar with the conditions that existed as to the St. Louis water supply prior to 1901 by records and by a visit in 1896.

Q. Now this opinion that you have given as to the effect of the Chicago drainage canal upon the waters of the Mississippi river at the intake—what was that based upon?

A. It was based upon the facts that the sewage entering the water courses above the intake, was nearly doubled by this discharge; that the distance from Chicago to St. Louis is very considerably less than the average distance of the other points of pollution, from the St. Louis intake; that the mixing of the waters in the channel of the Mississippi is such that the amount of sewage received at the intake is a large part of what it would be if the mixing were complete, and that the times of passage from the point of pollution to the intake were not sufficient to allow the complete destruction of the injurious and polluting matters discharged. The waters of the Mississippi and the Missouri and the Illinois rivers, of my own knowledge, commingle at the intake of the St. Louis waterworks. I know of my own knowledge that the waters of the Illinois river or some portion thereof, pass into the intake of the St. Louis water works.

2802 Q. What has been the effect, if any, in your opinion, of the discharge of the waters in the Chicago Drainage canal carrying the sewage of the Chicago Sanitary District, into the Des Plaines river under the conditions existing since January 19, 1900, upon the water of the Mississippi river along the Missouri shore, and particularly as drawn from the intake tower of the St. Louis waterworks at the Chain of Rocks, with reference to its use for drinking and domestic purposes?

(Objected to.)

A. It seriously injures the quality of the water.

CROSS-EXAMINATION by General Hamlin.

Have been engaged as civil engineer in establishing filtration plants for eight years. During that time have personally, and under my direction, installed sixty or seventy plants.

2803 I have made designs for others which I have not myself built. I was in St. Louis as a member of the Commission, composed of Mr. Williams, Mr. Wisner and myself, for the purpose of making investigations to determine the question how best to supply St. Louis with clear and wholesome water. The discussing and determining the question of filtration was part of the main question. The report we made was divided, Messrs. Williams and Wisner reported for a gravity supply from the Merrimac river and I recommended the continuance of the Mississippi river water with filtration. At that time the intake was established at the Chain of Rocks, where it is now.

2804 I made an estimate of the cost of filtration. I could give you an approximate idea of it,—about $2,000,000 for filtration plant proper, and $[illegible]90,000 or $800,000 for auxiliary works,—something like $3,000,000 for the whole project required by the present requirement of the city. In a large part my business has mainly been the making of designs and construction of filtration plants. That is the department of my work upon which I am able to speak advisedly. I have not made a chemical analysis or bacteriological examination of the waters at St. Louis. That is not [illegible]epartment of my work. I have made, in years gone by, chemical analyses.

2805 I do not remember how many times I have been employed to advise in suits that were brought by a city against a water company. In all cases that I have mentioned, where I have advised the installing of filtration plants, I have not taken the opinion of others as to the pollution. I usually make a personal examination in each case. In my reports I have depended principally upon my own investigations. As to the pollution of St. Louis I made no chemical analysis of the water because it was not necessary.

2806 Based upon either bacteriology or chemistry I have no knowledge at all other than what I got from some other source. I had analyses from other sources but the deductions to be drawn from those were entirely my own. Take the Ohio case. I had a report of the State Board of Health showing the conditions as they found them and I drew deductions from those reports and the other facts in the case. In many cases my main business was to install filtration plants; I drew the designs, made the plans and estimated the cost and I have superintended the work. In most of the cases I mention I have superintended the work unless I mention otherwise. I have a practical as well as a professional knowledge of the actual construction of this kind of work. It is a large part of my business. I am of the opinion that there should be filtration in St. Louis.

2808 It would cost more to establish a filtration plant, if one was necessary, if the Mississippi did not receive the waters of either the Missouri or the Illinois, because the character of the water of the upper Mississippi is different physically from the water of the Missouri. I have not studied the kind of plant which would be necessary for the Mississippi water above the Missouri but I think it would be very different from the plant required for the Missouri river water. Whether it would cost more or less I don't know at this time. Suppose you eliminate the Illinois river and put in the Missouri and Mississippi river, it would make no substantial difference.

CROSS-EXAMINATION by Mr. Todd.

2809 I first investigated the water supply of St. Louis in 1896. Next was in July, 1901, upon my appointment upon a commission for that purpose.

2810 In 1896 I did not examine it in a way to enable me to have an opinion upon its quality. (States examination in detail that was made in 1901, which is similar to that testified on direct examination.) In examining the waters of the Missouri, I examined the plants of the waterworks at Kansas City, Kansas, Kansas City, Missouri, St. Joseph and Omaha, to find out the character of the Missouri water and the methods which were necessary to treat it and the results which could be secured by those methods.

2811 In my examination of the Omaha waterworks I assumed that the sewage from Omaha and Council Bluffs entered the Missouri. I assumed that the sewage from Kansas City, Kansas, and Kansas City, Missouri, emptied into the river. I assumed that all the cities on the watershed sewered into the water courses. I assumed that this sewage injured the quality of the Missouri river. I did not consider it a safe and potable water and I do not consider it so now. If the Illinois river should be dammed at its mouth and a channel cut whereby it should empty below the intake tower of St. Louis, I would not consider the water of the Missouri and Mississippi which entered the intake tower at St. Louis a safe and potable drinking water. Assuming that a channel cut from the Illinois river should empty into the Ohio at Cairo, thus eliminating entirely the Illinois river water from the Mississippi between Cairo and Grafton, I would not consider the water of the Mississippi at Cairo a safe potable drinking water.

2812 I think that the discharge of the sewage into the Mississippi river by St. Louis and cities in Missouri emptying their sewage into the Mississippi river, as well as the cities on the Missouri emptying their sewage into the Missouri river renders the waters of the Mississippi above Cairo less wholesome and less potable. I cannot say that it renders it unwholesome and unpotable because it may be that it would be unwhole-

some and unpotable without them. By the comparative term "less wholesome" and "less safe" I mean that it would produce or might produce more sickness and more deaths among those who use the water.

2813 Assuming that the waters of the Mississippi above its confluence with the Missouri and the Missouri above Kansas City were non-polluted streams and assuming that the sewage was discharged into those rivers by the cities in Missouri, I should not off-hand consider the waters of the Mississippi river above Cairo a safe and potable water.

2814 I would not consider the water of the Mississippi river above Cairo under the conditions existing in the last statement, but with the additional information as to the rate of current and time of flow in the Missouri river and the Mississippi river, a reasonably safe drinking water after it had received the addition of the sewage from these different cities in Missouri. A water classed as good 20 years ago is classed as bad now and a water that satisfies us today probably will not satisfy the most exacting people a generation hence. Assuming that in the southeast corner of Missouri a company was about to establish a large city and conditions existing along the Mississippi above that point were such as are contained in the last hypothetical statement made, and I should be selected as sanitary engineer to look out for its water supply, knowing the conditions such as I have assumed them, and before I could ascertain whether this water was going to kill anybody or not, I do not think the waters of the Mississippi, under those conditions would be a safe drinking water for the future inhabitants of this supposed city without being artificially treated. (Objected to by General Crow.)

2815 I would not consider that water a safe drinking water. Assuming that the Illinois river was entirely eliminated from the waters of the intake, I would not consider the St. Louis water a safe drinking water with the water system as it now exists. The cities bordering upon the Illinois river and the conditions that obtained prior to January 17, 1900 would not

make the water supply of St. Louis a safe and usable water supply under existing conditions, in my judgment.

2816 The conclusion that I reached in my investigation of typhoid conditions in Chicago in 1892 was that the typhoid resulted from the sewage that entered Lake Michigan and got into the water supply. I presume some one else arrived at that conclusion before Prof. Sedgwick and I did. I was aware that the Sanitary District Act had been passed in '99. The purpose of the intercepting sewer system in Chicago is to keep the sewage of Chicago from entering the lake and diverting it to the drainage canal.

2817 Have investigated the waters of Lake Michigan. If the Chicago sewage was excluded the water of Lake Michigan would be safe and potable. If the Calumet district on the south and Evanston on the north should be added to the sanitary district of Chicago and all that sewage should be diverted into the drainage canal, it would improve the water supply of Chicago. When the entire sewage from the population of Evanston on the north to the Indiana line on the south is diverted from Lake Michigan, the waters of Lake Michigan will become safe and potable, if you go out far enough.

2818 I could not tell you the distance out that you would have to go—not offhand. I would not necessarily consider the location of the present intakes as being a safe distance from shore, owing to possible overflows and the sewage from shipping. I think the completion of the intercepting sewers of Chicago will reduce the typhoid death rate. (Objected to by General Crow.)

2820 So far as the typhoid infection is concerned, the infected sewage of Chicago will be greatly lessened when those conditions obtain.

2821 I have given the subject of the drainage canal and the sewage conditions in Chicago considerable thought and study. The Chicago river enters the drainage canal at Lockport. I do not remember the name of the place where the Chicago river and the drainage canal meet. I do not know the

ength, the width, the depth nor the capacity of the drainage anal. Dilution of sewage polluted matter, if the water which s used for the dilution is aerated, furnishes more oxygen in roportion to the matters requiring oxygen and so changes more r less radically, according to the character of the changes which ake place in the oxidation and fermentation of the sewage.

2822 From my observation of the water flowing out of the Chiago river, as I have seen it in the last few years, it looked to ne as if there was dilution sufficient to give an excess of oxygen and I do not doubt that that is the case.

2824 An increased dilution of water to the sewage of Chicago would not lessen and mitigate its dangers to St. Louis. The matters which would cause damage in the sewage which we know most about are bacteria. The typhoid bacteria are the best known and best studied but there is every reason to believe that there are also other kinds which are harmful. I have given their life history, their relations to water supply and disease, study. I have never studied them in a laboratory with a microscope. The explanation I have for the fact that the typhoid bacillus has never been found in the Des Plaines, Illinois and Mississippi rivers is that it is a difficult matter to find it. The amount of water that can be examined effectively for them is extremely small and the infinitesimal proportion of the water flowing and failure to find in the small samples which can be examined is not evidence that it is not present.

2825 The failure to find it is not evidence that it is present. Sedimentation would remove some of the objectionable matters from sewage and put them upon the bottom of the stream. Aeration tends to purify sewage polluted waters. In my investigation I did not ascertain what facilities existed between Chicago and St. Louis for the aeration of the sewage in the waters, any more than a general knowledge of the conditions and I assume, as I believe to be the fact, that oxygen is in excess throughout. I do not know how far it is from the Chicago river to the end of the canal. I should think that the conditions

which obtain at Bear Trap Dam are such that they might tend to greatly increase the aeration and oxidation of the waters. I don't know certainly. I have never seen the conditions which obtain when the waters pass over the Bear Trap Dam.

2826 I don't know what the effect of that waterfall is upon the waters of the canal. After the waters leave the controlling works at Lockport I do not know how far they flow before they enter the Illinois river. I do not know whether there are many lakes along the Des Plaines river. If there are lakes, where the current is very slow, such places would require much more time for the passage of the water and so would afford facilities for purification; it would tend to increase sedimentation and the sedimentation that did settle would be eliminated from the water as it passed off, for the time being. I have never investigated the conditions that obtain in Lake Joliet and do not know whether there is such a thing as scouring which takes place in the lake,—I only observed it as I passed on the train.

2827 From La Salle down, did not observe conditions of the river. Have seen records of how many dams are located in the Illinois river. The effect of those dams is to retard the flow somewhat. Could not say how far from the dams is the effect of those dams experienced by the waters of the Illinois river up-stream. If it should run up from 25 to 50 miles, that would increase the sedimentation when it operated that far. I do not know how long this sewage would have to lie upon the bed of the river in order to be made non-injurious. In the Millbury case, we were confronted by the proposition, backed up by very eminent experts, that the trouble that our people were experiencing, was due to sewage mud which had been deposited prior to a time some years before and that was the cause and the sole cause of the trouble. To some extent the conditions in that river were similar to those in the Illinois river. I believe the Illinois river is a river which is scoured by freshets or high water.

2828 I should rather have the judgment of one who understood the subject and who studied the floods in ascertaining whether the Illinois is affected by scouring. That would be by asking the inhabitants along the river. I would rather have one who understood the subject and who watched the flow of the river in floods. I think that would be more conclusive than the judgment of those who live along the banks.

2829 Supposing there are floods along the Illinois river, the best means of ascertaining whether the bottom of the river where sedimentation has taken place, has been disturbed by these floods, would be by seeing if the current was such that it would stir up and carry away such deposits. By inspection I have no opinion as to what amount of deposit has been made in the Illinois river above the dams. If there was a foot or six feet of sediment on the bottom of the stream above the dams, it could be established by soundings. As to whether deposits are disturbed by the freshets so-called from the Illinois river, I have only my knowledge as to what happens generally in rivers. I do not understand what period of the year the Illinois river flows between its banks nor how many acres of land are overflowed throughout the year by the Illinois river. If it should appear that there was an excess of 500,000 acres of land inundated outside of its banks, the sedimentation would undoubtedly be much greater in that portion of the stream outside of its banks, where the water was shallow and the current was slow. The scour might or might not be less but that I don't know.

2830 I did not examine any waters of the Illinois river prior to 1900 excepting some samples from La Salle. Am not acquainted with the size and dimensions of Lake Peoria, nor the condition of the water before or since the opening of the canal above Peoria, nor whether the water of the Illinois river above Peoria is less polluted today than it was prior to the opening of the canal. I assume that the sewage of Peoria pollutes the Illinois river.

2831 I do not know how many distilleries or factories are located at Peoria. I have no idea of the number of cattle

that are fed along the banks of the Illinois river by the distilleries. I should say that the ratio of sewage of Peoria and Chicago was in proportion to their respective populations. I have no knowledge as to how much of the Chicago sewage has been eliminated from the waters of the Illinois by the time it gets to Peoria. The amount of sewage at Peoria would not be as great as the amount that passes over the Bear Trap Dam.

2832 I do not think that any part of the sewage has been eliminated by the time it reaches Peoria but some of the constituents have been eliminated. I don't know if the pollution of the waters at the Bear Trap Dam would be as great as the waters of the Illinois. I presume that the water that passes over the Bear Trap Dam is more polluted than the water is by the time it reaches Peoria. The lessening of the pollution of the

2833 waters at Peoria is due to dilution, sedimentation, destruction of a number of organic matters by oxidation in the water, and the death of a portion of the bacteria. The water of the Illinois below Peoria would be more polluted than the water above Peoria. The wastes from Peoria probably contain enormous quantities of organic matter which make a perfectly tremendous show upon your chemical analyses, but which from a sanitary standpoint are of no significance whatever. I should suppose that the amount of infected matter brought from Chicago would be very largely in excess of the amount added by Peoria. That opinion is based upon my experience with streams in general, under conditions as I understand and assume

2834 them to be, but not upon any personal knowledge in regard to the conditions that obtain at Peoria itself. The waters of the Illinois river at Grafton, I regard as quite certain—beyond a reasonable doubt—are infected. I don't prove that proposition. I would like to prove it if I could. The proof would necessarily be somewhat indirect and circumstantial. It has perhaps never been absolutely demonstrated. The increased death rate in St. Louis since the opening of the canal is a very strong indication of it. If we eliminate St. Louis for the time being, I don't know about the possibility of demonstrat-

ing it at Grafton. I believe the waters of the Illinois river at Grafton have been proved to be infectious and polluted.

2835 The best available proof is the increased death rate among those who use it. I don't know of anyone who uses the waters of the Illinois river at Grafton, or immediately above it. If it should appear to me that a great number of people fishing on the Illinois river, living in flat boats along the Illinois river—a floating population of several thousand, was using this water for drinking purposes and that typhoid was a thing almost unknown among those people, it would be an interesting consideration and I should consider it.

Q. If you saw these people drinking and knew that these people drank that water and you knew that these people did not have typhoid fever as a consequence of drinking that water, would you not draw the conclusion from that fact, that the water was not infected?

A. If there were a sufficient number of people; if the evidence was clear and conclusive on the point that they drank the water and that they drank it straight, and that they did not have typhoid fever, it would be a very important piece of evidence. If the evidence showed that in the cities along the Illinois river where great numbers of people were engaged in the fishing industry, and that these people should contend that the water of the Illinois river is better today than it was prior to the opening of the canal, and that they drank the water and experienced no deleterious effect from it, it would not be strong evidence to my mind, as a sanitary engineer that that was not infected water. That is an entirely different proposition. The men who use the water as you say, would measure its character by its appearance and the addition of the clear, colorless lake Michigan water.

2836 The fact that a number of people would testify that they drank it and did not have typhoid would be valueless in the absence of the complete record about which you speak, because even with the most polluted waters, a large majority of people drinking such water escape while only a small minority

contract disease and suffer. In order to make the evidence of value, it is necessary to have a definite population and to get the statistics of sickness and death for that population—to show that a large number of people use the water and do not suffer from it, is entirely inadequate.

Q. Then, assuming that you eliminate St. Louis and disregard the evidence of the people who use the water along this river, how can you determine whether or not the water of the Illinois at Grafton is an infected or non-infected water? (Objection by General Crow.)

2837 A. If we eliminated the evidence in this particular case, there might be no proof. We could still form an opinion and back it up on very good grounds, that the water would be injurious, because of the large proportion of sewage which it contains, and the fact that the time required for the sewage to reach that point is insufficient to allow complete destruction of the deleterious matters contained in it. The chemical analyses can never show infection of the water. They can only show pollution and infection can be sometimes inferred from the pollution.

Q. Then the way you ascertain a conclusion that a water is infected is by its use and effect upon the inhabitants, on the people who use it?

A. If that evidence is available it is about the best, usually. If it is not available, we have to resort to indirect methods, methods which have been established by experience in other cases, and which when reasonably applied are reliable. I have been told by people who have studied the matter that it takes the sewage of Chicago two weeks to go to the intake at St. Louis.

2838 I don't recollect how far it is from Kansas City to St. Louis. If it is 400 miles away and the time required for the water to flow from Kansas City to the intake of St. Louis is four or five days, and if you should have in Kansas City 490 cases of typhoid in a year, I think both Chicago and Kansas City

would be contributors to the death rate in St. Louis. As to which would be the more generous contributor, Kansas City would be nearer in point of time. In point of population Chicago would be much greater. I should think probably the extra population of Chicago would more than offset the extra time, but that is a matter which from the nature of the case, could not be determined with precision. The nearer the water supply, measured by time, is to the source of contagion, the greater the danger.

2839 If it should be shown that there was a general increase in typhoid over the Mississippi valley co-incident with the increase in St. Louis, it would tend to show that the pollution from the cities up the valley contributed more to the increase in St. Louis, and the addition of the Chicago sewage less, than I should suppose under opposite conditions. I have not given the question of the increase of typhoid fever for 1900 and 1901 in other cities outside of St. Louis any consideration. I understood that in some parts of the country cases of typhoid were brought into this country by soldiers of the Spanish-American war. I do not know what position St. Louis occupied during those years, 1900 to 1902 inclusive, as to being a central point for returning soldiers from this war, to separate and go to their homes.

2840 An increase of 30 deaths in St. Louis in a year is a substantial increase. If the total number of deaths in St. Louis was 168 for a year, as to whether it was an epidemic or not, I would leave to the doctors. The fact of the increase has significance to me as a sanitary engineer but whether it is called an epidemic or not is something which I would not attempt to say. Under our system of registration, the record of deaths is much more reliable than the record of cases. If it should appear that in the city of St. Louis in 1900, 1901 and 1902 the death rate was a gradual increase and the number of cases was a gradual decrease, I should think there was a new kind of germ—a more active kind, that was getting into the water.

I should give the record of deaths much greater weight than the record of cases, because while the percentage of deaths not reported is comparatively small, a large number of cases, even under the most stringent laws in this country are never reported.

2841 Q. It is not an easy matter for an ordinary practitioner to diagnosticate a case of typhoid fever, is it, Mr. Hazen?

A. I understand there is doubt sometimes. Assuming that in St. Louis for these three years particular effort was made by the Health department in sending out letters to all practicing physicians, to report cases of typhoid fever and deaths, and these tables that I have given were the results obtained (See record 2840) I could not accept that record as true, because the ratio of cases to deaths is such that it would indicate a clumsiness on the part of St. Louis doctors.

2842 I recognize the fact that different doctors of different degree of talent have greater or less success in the treatment of typhoid cases. I presume there is a difference of skill.

2843 Assuming that in 1900 in St. Louis there were 1213 cases and 168 deaths from typhoid and in 1901 there were 1101 cases and 198 people died, I should say that the typhoid for those two years in St. Louis was on the increase.

Q. In other words, the more people that die and the less number of cases, would be indicative of an increase in typhoid fever, and if few people died, and more cases prevailed, it would be on the decrease?

A. That would in general be my conclusion, but I think a full accurate statement of that would include data upon both points. I would consider the waters at St. Louis prior to the opening of the drainage canal as dangerous for drinking purposes. There may be additional cost for a filter for filtering bacteria, in the construction of filters, aside from the filtering of mud. In the case of St. Louis, there would not be a material additional expense.

2844 I expect as the water of Chicago becomes less contaminated from sewage by the city, by diverting sewage into the Des Plaines river and the public health of the city becomes improved, the infectious material entering into that river will gradually become diminished. In proportion to its diminishing, in just such proportion does the danger of that water in the Illinois river decrease to those using it so far as typhoid fever is concerned, but as I said this morning, from the best data I can get, where there is one death from typhoid fever, there are several deaths from other diseases shown by the general death rate which come from the preponderance of the diseases there. I would put it this way,—when a city has a bad water supply and does away with it and gets a good one, the general death rate falls. The subject is speculative, to some extent. The question of the effect of Chicago sewage upon St. Louis is speculative to some extent. I saw the mixing of the waters of the Mississippi and Illinois. That is a thing susceptible of demonstration by the naked eye.

2845 The mixing begins at the mouth of the Illinois and is not absolutely complete by the time it gets to the mouth of the Missouri; it is approximately so, and more so at low water than at high water. The Missouri river water entering the Mississippi commingles and mixes before it reaches the St. Louis intake. The proportion of Illinois river water at the intake is variable. It can be substantially demonstrated, but not precisely.

2846 About 30 per cent Mississippi water and 70 per cent Missouri river water enter the intake. I could not say how much of that 30 per cent I would call Illinois water. I could not tell if it averaged 5 per cent. I think it averages something because it mixes with the Mississippi and the Mississippi mixes with the Missouri. It completely mixes on the west side of the Mississippi. I did not follow it down because I regarded it so obvious that it was not necessary to do so. I assumed that to be the fact. I did not demonstrate it. I can see it. I regard ocular evidence as all sufficient for that purpose.

2847 I expect that the Mississippi river water runs up to 70 or 80 degrees in the early spring and down to 10 or 15 degrees in the July rise in the Missouri. It probably varies from year to year—constantly varies. The dike at the intake would have the effect of throwing the water of the Missouri river out towards the intake.

CROSS EXAMINATION By Judge Springer.

I found the water of the Potomac to be somewhat polluted and objectionable.

2848 I recommended filtration—a combined system consisting of the use of coagulants at times of flood only, settling, and after settling, filtering. That system has been adopted as to the filters. The provision for applying the coagulant has never been officially adopted. Where the deleterious properties of water are the result of ordinary sewage pollution from the sewage of cities and towns in the river districts and that only, my system of purification is to filter the water through sand, as is done in Europe, where the conditions are favorable for that.

2849 The pollution that comes from the natural rise of rivers, where rural districts are washed out, and farm and breeding lands and small villages are washed out is an important element. There are saving features, if it comes at a time when the flood is greatest; if that amount of pollution were put in the rivers at low water flow, it would be most disastrous. When I passed upon the question of a water supply for St. Louis I considered particularly the removal of the mud which comes largely from the Missouri, the color which comes largely from the upper Mississippi and the sewage pollution which comes from all of them. It was a system of settling the water first, to remove the grosser matters; then coagulate it; then settle it again and then taking it to mechanical filters and then to clear water reservoirs; then to the pumping stations in the city. I consider that the water after passing through this process would be a satisfactory supply. So far as the large

rivers are concerned, it is true that where I have been consulted in regard to water supplies for cities, I have recommended some kind of artificial treatment before the use of the water, but it is not true with reference to smaller streams and lakes. When I took into consideration the various conditions to be overcome at St. Louis, I was aware that the drainage canal had been opened and that the sewage of Chicago was emptied into the Des Plaines river. Having that in mind and the large amount of water in suspension in the Missouri river and the turbidity of the upper Mississippi, I reached the conclusion that
2851 a wholesome, safe water supply could be obtained for that city by the use of the system which I have described. The cost of construction, including the auxiliaries was something under $3,000,000. I have not the exact figures. Of course, the operating cost would be in addition to that. The cost would not be materially reduced if you could eliminate the water that comes into the Des Plaines river from the drainage canal.
2852 I could distinguish the waters of the three rivers because where they come together, the Illinois river water has a low color and the Mississippi water is yellow. For a little way below you could see nearly colorless water on the Illinois side but it only went down a short distance and went across so that no difference was perceptible. There is not so much difference in clearness but the Illinois river was nearly white and the Mississippi was quite yellow. The cause of that difference in color was the peaty matter in the Mississippi river water.
2853 The Illinois river water was a nicer looking water. I should think that as it tended to increase the pollution of the river it would tend to be objectionable for farming purposes along the line of the river below St. Louis. I presume that it would not be large in its influence below St. Louis, especially for watering stock and cattle.

RE-DIRECT EXAMINATION By General Crow.

No amount of dilution will remove typhoid bacilli from

water. It simply reduces the proportion and minimizes the danger of receiving it. Besides putting in filter plants, I have been engaged in purely chemical work also.

2854 That was at Lawrence, before I went to Chicago. My title was chemist in charge of the Lawrence Experiment Station. For five years I had charge of very important chemical work at that station in Massachusetts. I had charge of chemical work frequently in Chicago but I always got some one else to do it for me in Chicago and I have not attended to it personally. I have been consulted and have advised different towns and cities as to the disposal of sewage without reference to the supply of water.

2855 Aeration does not destroy typhoid germs. At the time of the investigation of 1901 in St. Louis, I was familiar with the chemical and bacterial data that was under the control of and accessible to the city authorities at that time and these were taken into consideration by me in my report and in the opinion I have expressed today.

2856 I had the figures as to the width, depth, relative flow of the water and speed thereof, so far as the Drainage canal is concerned and have studied them at various times, but in my cross-examination I did not have them accurately in my mind and could not state them off-hand. The operation of filtration does not absolutely eliminate the objectionable matters in the water. It reduces them very largely, but as the removal is not complete, if the amount of pollution of the raw water is increased, it does increase in some manner, the danger from the use of the filtered water.

2857 I have had records which show that the Illinois river carries suspended matter at times. That would indicate that it scoured. The proposition of putting in filter plants is only one of the different lines of mechanics that go to make up my profession and it is an important one.

DR. W. W. WILEY examined in chief by General Crow.

2858 Am a physician and reside in Cumberland, Maryland. Have lived there 30 years and practiced medicine about

that length of time. Am still engaged in regular practice there. Cumberland has a population of about 20,500 and is located in Allegheny county on the north branch of the Potomac river. By rail, it is 153 miles from this city (Washington. D. C,) to Cumberland; by river, it is about 204 miles; by Chesapeake & Ohio canal, it is 184 miles. There is a sewer system at this time in Cumberland.

2859 The typhoid epidemic commenced in Cumberland about the 10th of December, 1889. It first struck my attention when called to see a young man sick with typhoid fever. It continued until June, 1890, and increased in severity. In the early part of January they cropped up and in February more than in January, and more in March and then it dropped off in April and May. After that we had a few cases. There was no health record kept by the city government. There were at least 485 cases reported by the physicians' society. (Motion to strike out by Mr. Todd as incompetent.) There were a great many cases of my own personal knowledge besides those reported.

2860 To be within the limits I would say that I had personal knowledge of 270 cases,—those that I attended and consulted with. The fever was pretty well scattered over the town. Indirectly there was sewerage connection with the Potomac river. There were private sewers running into small streams and they emptied into the Potomac. The town is pretty evenly divided in half by Wills creek, which runs into the Potomac. There is a stream known as Sulphur Run which comes down Fayette street on the west side and joins with the one coming down Green street and they together empty into the Potomac. At that time it was above the waterworks, about 175 ft. above the intake. In December, January, February, March and April there was water in all of these streams.

2861 I know of my own personal knowlede that some of the houses in which people were ill of typhoid fever in 1889 and 1890 had direct sewer connection with either Willis creek or Sulphur Run. At that time the physicians generally ordered the disinfection of the dejecta of patients. They did all that

was in their power. Of course in private practice you cannot carry it out rigidly. Where it is attempted to be done it does not result in the destruction of all the germs anyway.

CROSS-EXAMINATION by Mr. Todd.

2862 At that time we had no general sewerage system. Individual sewers were running into this run or into Wills Creek or into a place called Millrix, or directly into the canal. Not over 20 per cent of the population had their closets in their houses. The other 80 per cent used what is known as privy vaults. Many of these were built right over the edge of the streams and it was carried directly into the river. The population at that time was about 12,000 of which there were about 3,600 people adjacent to the streams. I do not know how many people had typhoid fever that occupied houses whose privies overlooked these different streams.

2863 In that part of the city away from the banks of the river, the epidemic was most prevalent. Decatur street, which is pretty far removed from any one of these streams had more of it I think than any street in town. Most of the sewers in that street were private and the household sewage was deposited in privy vaults. Those people on Decatur street almost nearly all used river water at that time.

2864 I don't know what caused the epidemic, only that the people who drank this water seemed to get typhoid fever and when the river was abandoned for drinking water, the typhoid gradually died out.

2865 The nearest town on that river is Keyser, 29 miles above. There were said to be two or three cases there at that time. I made no investigation of it. Cumberland has the Holly water system—the water being pumped direct from the Potomac and forced to the city. Of the 270 cases that I treated or had personal knowledge of, I should say that the fecal discharges of about 70 per cent, if not beyond, would go directly from the house into the sewer.

2866 Hancock, which is 60 miles below Cumberland, soon after

we had our epidemic, began to have cases and they accused us of communicating it to them. Exclusive of those cases that occurred in houses where the privies overhung the river, with the water running that way, it would take sewage a very few hours to get from the houses into the river.

2867 The sewage of a part of Cumberland itself entered the water above the intake and the water that got into the intake was contaminated and polluted by the sewage discharged from Cumberland itself. About one-third of the population drain into the river above the intake. At Cumberland the river is 300 yards wide.

2868 The deepest place is about 29 feet.

2869 WILLIAM B. STOCKMAN Examined in chief by General Crow.

Am District Forecaster United States Weather Bureau; residence, Washington, D. C. Have been in the service 25 years. Am in charge of the division of meteorological records. It has a record of the rain precipitation throughout the country. These two charts marked "United States Department of Agriculture, Weather Bureau," show the rain precipitation. They represent the mean annual rainfall of the various places mentioned or indicated. They are copies of the official record.

MR. TODD: I do not object to the form of the testimony but I object to its materiality. (Witness explains meaning of figures, etc., on chart.)

2873 (The figures show the mean annual rainfall at the places indicated for various years to the year 1895. Witness agrees to mail Commissioner Bright the same data for the years 1895 to 1903 for these stations.)

2874 Charts marked Complainant's Exhibits Nos. 71 and 72. Additional chart marked Complainant's Exhibit No. 73.

CROSS EXAMINATION By Mr. Todd.

2875 In getting these averages for the periods that I have indicated, we take the total for the months, and for the annual, we take the annual data. These figures, for instance, Chi-

cago, 34.76, mean the mean annual precipitation at Chicago in inches. That is true throughout.

WILLIAM C. WOODWARD, Examined in chief by General Crow.

Reside in Washington. Am health officer of the District of Columbia. Have lived here (Washington) my entire life, since 1867.

2876 Have been health officer of Washington since 1894. Have practiced medicine since about 1892.

2877 This statement showing the number of deaths from typhoid fever, typhoid malarial fever, malarial fever and diarrhoeal diseases, occurring in the District of Columbia each month from January, 1885, to December, 1895, inclusive, is a correct copy from records in my office. That is my signature attached to the certificate and the official seal of the District of Columbia. (Document offered in evidence and marked Complainant's Exhibit No. 74.)

2878 I have records of deaths from typhoid fever by months from 1895 to 1902 inclusive. (See record pages 2878, 2879 and 2880.)

2881 As a health officer of Washington, I have had occasion to make personal inquiries into the water supply of this city, but I have never investigated the watershed nor personally made bacteriological nor chemical analyses, though I am familiar with the work that has been done along both lines.

2882 My opinion after a careful consideration of the entire subject, is that the chief cause of our typhoid fever is our Potomac river water. Steps have been taken to remedy that. The Federal Government has in course of construction a filter plant to filter the entire public water supply of the District of Columbia by means of slow sand filtration. That was done by Act of Congress. The kind of pollution that renders bad the Potomac river at this point is human excreta, I think, and sewage pollution.

CROSS EXAMINATION By Mr. Todd.

I don't hold myself out as an expert on typhoid fever nor on causes of epidemics. I don't hold myself out as an expert on anything. I have carefully studied the subject of typhoid fever in the District of Columbia since 1894 and I have especially closely studied the subject of water supply here and elsewhere and as a result of that study, covering a period of nearly nine years, I have expressed that opinion. I have expressed
2883 the opinion and I stated my experience. I will leave it to the court to determine whether I am an expert or not. The Potomac river water is not absolutely the only cause of typhoid fever in Washington. We have direct infection of one patient to another, infection from milk, oysters and vegetables eaten raw, persons visiting here from other cities, or persons who are returning from summer resorts who develop the disease and then we have the class of persons who develop it either from drinking well water or Potomac river water.

2884 Of course the persons who contract it here and develop it elsewhere will probably even it up. I have no statistics showing the number of persons who contract it here and develop it elsewhere. From 60 per cent to 70 per cent of the total typhoids in Washington I attribute to the waters of the Potomac and the other 30 per cent or 40 per cent I attribute to the causes I have previously named.

2887 In table marked Exhibit No. 73 I have what is known as typho-malaria and typhoid fever. I regard a case of typho-malarial fever as a case of typhoid fever in which the physician has made a mistake in the beginning and called it malarial fever and he seeks the best way out of the hole. The typhoid death rate in Washington is high according to the U. S. Census figures, which I have recently gone over for a purpose other than this. There were about two large cities that excelled it in typhoid fever death rate, one was Pittsburg and the other Atlanta.

2888 I should say that the death rate should run down certainly not above one in 10,000 inhabitants, from typhoid fever.

2889 RE-DIRECT EXAMINATION by General Crow.

There are nine towns on the watershed above our intake. (Witness gives names of towns, populations and the distance in miles from the intake.)

2891 TESTIMONY OF THE DEFENDANTS.

On board the steamer "Illinois" at the foot of Vine street, St. Louis, Missouri.

AUGUST JOHNSON, Direct examination by Mr. Todd.

I live in Burnesville, Missouri. Took samples of water for the Sanitary District of Chicago opposite Jefferson Barracks in the Mississippi river in 1889 and 1900.

MR. JEFFRIES: I move to strike out the testimony in regard to Jefferson Barracks for the reason that it is irrelevant and does not tend to prove any issue in the case.

(States instructions received and the method of taking samples.) Sent the samples to the University of Illinois, University of Chicago and the health department at Chicago.

2894 CROSS EXAMINATION, By Mr. Jeffries.

Don't know whether the bottles had been sterilized when I received them.

2896 In 1900 collected samples once a week and sometimes three times a week.

HENRY ATKINS, examined in chief by Mr. Todd. (At Mitchell's Point on Mississippi river).

Live at Mitchell Postoffice, Illinois. Live about 150 yards

2897 from the Mississippi river. Was employed by the Sanitary District of Chicago to take samples of water from the Mississippi at the Chain of Rocks in 1899 and 1900. The instructions on the card, sample 2528, are those which I followed in taking the water. Took the water over to Mitchell's and shipped it to Chicago and Urbana. (Witness states method pursued and the places at which samples were taken.)

2900 CROSS-EXAMINATION by Mr. Jeffries.

2901 It would be about four hours before I would get over to Mitchell's with them. Two times is all I can recollect that we missed the train on special collections and had to hold the samples over until the next day.

2904 Collected once a week up to July, 1900. After July, 1900, collected three samples three times each week.

F. M. CALHOUN examined in chief by Judge Johns, (At Alton, Illinois.)

Am a fisherman and reside at Alton, Illinois. Have been employed by the State Board of Health in taking samples out of the Illinois river at its mouth and the Mississippi also. The Illinois river about two miles above Grafton and the Mississippi river about half a mile above the town, across on the other side of the channel of the Mississippi. The samples taken in the Mississippi river were taken above the mouth of the Illinois, that is, from where the Illinois water could not possibly reach the Mississippi water at that place.

2905 (Witness states method pursued in collecting samples and the points from which samples were taken.)

2908 (Cards and envelopes used in connection with the shipping of samples, marked Exhibit No. 1 for the State of Illinois, for identification. Same as to two more bundles of cards and envelopes, marked exhibits No. 2 and 3 for the State of Illinois for identification.)

2909 I lived ten years in Grafton. During that time my business was fishing with nets. Prior to 1900 assisted in putting up ice, every year that the ice was fit to put up during that time. Fished every year for eight years prior to opening of canal and for two years after the opening of the canal.

2910 Prior to the opening of the canal, take this time of the year, in low water, the Illinois river was very stagnant. Not a very good current in it and therefore it was in bad shape. After the canal was opened, it never got so stagnant as it did before. We could fish it different before you turned the canal in than we could afterwards because the current interfered in

part of our way of fishing. Of course we all considered it was better by having a good current. Before the canal was turned in, there would be a green scum form over it and you couldn't tell whether it was very clear or not. We had but very little of that afterwards. Used the water for drinking purposes part of the time. The fishermen living on the river in my vicinity use the water of the Illinois river for drinking purposes. (Objected to by Mr. Johns.)

2911 It was better in cold weather for drinking purposes. It was not so good before the canal was turned in, when that green scum was on it. We drank it before and afterwards just the same. Couldn't tell any difference in the ice before

2912 or after the opening of the canal.

CROSS EXAMINATION By Mr. Jeffries.

2914 There is no scum on the water now. The current keeps it carried off. That is about the only difference in the water so far as appearance is concerned. The real difference is that there is a running current now, when before, at times, there was no current. If the back water from the Mississippi stood in the Illinois long enough a green scum would form very likely in hot weather.

2915 That green scum didn't form on the waters of the Illinois when there was no back water from the Mississippi river in there before nor after the opening of the canal. My idea of drinking water is good, clear, pure water; water that is clear and cool I would pronounce good drinking water if it had no stench to it. That is my idea of the Illinois river water. I think it is about as good as any—about as good as well water.

2916 I drink it at any and all times of the year regardless of its appearance. There is considerable more current now than there was before the opening of the canal. The volume of the water coming down the Illinois river now at all times of the year is far in excess of what is was prior to the opening of the canal. There is no back water in the mouth of the Illinois except when the Mississippi river is high. At ordinary stages

it runs out regularly down to the Mississippi, with a distinct, rapid current—a fair current.

2917 GUST BAILEY, Examined in chief by Judge Johns.

Am a fisherman, except when I was collecting water. Reside at East Alton. Have been engaged in taking samples of water for the State of Illinois.

2918 (Witness states method of taking samples and the places where samples were taken.) Cards marked Exhibit 4 for the State of Illinois for identification are in my hand writing.

2922 GEORGE BROOKS, Examined in chief by Mr. Todd.

Live in Alton. Collected water for the sanitary district of Chicago. (Witness states methods pursued and places where samples were taken.)

2927 Sample tag No. 2222 marked "Sanitary District of Chicago's Exhibit No. 3 for identification."

2928 JAMES MATTHEWS, Examined in chief by Mr. Todd:

I live on Little's Island just above the bridge in the Missouri river. Took samples for the Sanitary district, the State University of Illinois and the University of Chicago, in 1899 and 1900. (Witness states method pursued and places at which samples were taken..) Card No. 9746 is in my handwriting.

2934 V. J. SCHUMACHER, Examined in chief by Mr. Todd, (at Grafton, Illinois.)

Live at Grafton. Am pilot on the Illinois and Mississippi rivers. Have been pilot for six years.

2935 Prior to that was steamboat engineer or mate, either one, for 14 years on the Mississippi and Ilinois rivers—mostly on the Illinois. Have been acquainted with the waters of the Illinois river for 32 years from St. Louis to LaSalle, Illinois. Prior to the opening of the canal the water of the Illinois river was green. The water from—well, we will say from Beardstown up—it stunk. We could not drink the water, it would foam the boilers, but now we can go along and drink

the water. We pump the water and use it on excursion boats—before we could not.

2936 Before the canal was opened it had a green scum on it. It smelled bad. It was not fit to drink. We would have to get water from the shore, but since the drainage canal has been opened we don't have to do that. Before the opening of the canal we would find dead fish floating in the river—tons of them—floating in the river above these dams. Since the opening of the canal we have had better water and better fish.

MR. JEFFRIES: I move to strike out the testimony of the witness that water is purer since the canal was opened than prior thereto, for the reason that witness is not qualified as an expert.

Those dead fish were found at Copperas creek dam and also at the dam below Beardstown, also at Kampsville. We found them up there every time we would go through. We found the green scum plumb up to LaSalle. It would generally go down about to Alton before it would begin to vanish.

2937 I don't know that there would be much difference in the water at Grafton as compared with that at Beardstown and at Pekin. Of course, further down the river the water would naturally become more pure on account of the current in the river. Those distilleries at Peoria would have great piles of stuff in the river. It would lay there and a steamboat would come up and throw great mounds of it up into the river and the water would stink. We don't see that any more. The water was always better above Peoria than below. It was some better than it was below because it was stiller up there, because the sewage business could not go up the river and consequently it didn't have this bad green smell and look to it that it had below Peoria always. We find we have a good deal better water in the channel now than we had before. Before the opening of the canal we never drank the water at all. We would dig holes along the banks or the shore, or sink pumps down and get the water that way.

2938 In my opinion as a layman and a man who has observed the conditions along the river, the water has been better since the opening of the drainage canal. It has been better to drink and better to use in every way. The green scum has not entirely disappeared but more so than it ever was before. The odor of the water has disappeared and the water has become clearer than heretofore.

2939 I believe the water at Grafton is better now than it was before. There is a good deal of difference between the water at Grafton and at Pekin. It is like a man taking a drink of river and taking a drink of spring water, like where there has been rotten fish or somebody had been laying in it. I would not want to drink the water there. Here, we drink the water all the time when we are out in a skiff. I do not know how many people live along the Illinois river from LaSalle to Grafton in fish or flat boats, engaged in the fishing industry, who live upon the river and drink the water of the river—there is too many of them. There is more than I could tell you. There is so many that live upon the river in cabin boats that I couldn't tell you and tell the exact number that is there.

Q. Does it run up in the thousands?

A. Well, it gets pretty close to it I believe, yes sir.

2940 CROSS EXAMINATION, By Mr. Jeffries.

I have known this river 25 years. A green scum formed on the Illinois river prior to the opening of the canal during the summer season or late in the fall until the ice would drive it out. It extended from bank to bank all up and down the river.

2941 We have a current now and we have a little scum now. There has been no scum to any great extent. There are no additional waters coming into the river today other than those from the drainage canal. The water from Lake Michigan coming through the canal is the cause of the additional volume of water in the Illinois and the current that now exists in the river.

2942 The current purifies the water. Where there is no current there must be stagnated water. I am not attempt-

ing to give the reasons why the water since the opening of the canal is better than it was before. I am simply stating what in my opinion is a fact.

2943 The main reason I say the water is better is because the water is better and I know it is better from using it and the hundreds and hundreds of people that we carried on the steamboats using the water and not kicking against the water.

B. F. ROBINSON, Examined in chief by Mr. Todd.

Live at Grafton. Took samples of water for the Sanitary district of Chicago, Chicago Health Department, University of Chicago and University at Urbana. (Witness states method pursued and places where samples were taken.)

2948 JAMES M. ALLEN, Examined in chief by Judge Johns:

Reside at Grafton. Am retired miller and President of the town council. We were formerly located on the Mississippi river but since the Government has built dikes between Calhoun county and the island opposite, we are now located on the Illinois river. Formerly the mouth of the Illinois river was two miles or more above Grafton. Have lived here 56 years.

2949 Prior to opening of the drainage canal the water in the Illinois river at times was almost stagnant. At times there was an odor. The water was not used for drinking purposes, when we could help it. Frequently it was covered with a green scum. At the times I have seen it since the opening of the drainage canal it has been better but whether it has always been better I couldn't say.

MR. JEFFRIES: We object to any testimony from this witness upon the character of the water for domestic or drinking purposes, for the reason that he has not qualified as being possessed of sufficient scientific knowledge to express an opinion or belief as to the sanitary condition of water; for the further reason that experience shows that various people will insist upon drinking certain water known to be diseased and infected, with no other excuse than that the water is clear water, and for that reason the testimony of this witness as a layman is immaterial, irrelevant and incompetent.

It is agreed that the above and foregoing objection shall apply to all testimony of all witnesses whose testimony is taken upon the Ililnois river, who are not experts, and that this objection shall be treated and considered as applying to all such testimony, without its being further stated. (F. S. B. Com'r). It was purer and looked better. Grafton's supply is from wells and springs. I do not think any portion of the population obtain water for domestic purposes from the river.

2950 As a usual thing it is Illinois river water that is next the shore on the Mississippi river at Grafton. There are times though, when the Mississippi river predominates, that is, where there is a rise in the river and the Mississippi is higher, the current comes through to this shore and we get Mississippi water, frequently backing up the Illinois river for some miles. There is a population in and about Grafton engaged in the business of fishing. I suppose to a certain extent they drink the water of the Illinois river since the opening of the canal. Since the opening of the canal there has been stagnant water having a green scum upon it in the river near this point. That was in 1901 I think, along in the summer months; it was unusually dry.

CROSS EXAMINATION, By Mr. Jeffries.

I say the water is better for the reason that there has been a larger body of water and the current has been stronger.

2951 It is perhaps a mile and a half. I always have believed that water will purify itself in a running stream. The water has a better appearance and is not sluggish and there is not as much of that scum on the surface as it formerly had. When I speak of the water of the Illinois river being better now than prior to the opening of the canal, I speak simply from my observation of the water rather than from its use by me.

Grafton has a population of 988.

2952 WESLEY PARK, Examined in chief by Mr. Todd.

Have lived in Grafton 14 years. Am practicing physician and surgeon and have been for 43 years. Am acquainted with the Illinois river between Grafton and Hardin, but not much above Hardin. Hardin is about thirty miles from here

by river. I did not notice any difference in the water at Grafton and Hardin prior to the opening of the canal.

2953 Since the opening of the canal the water at Grafton is better, purer, cleaner and has greater current. Before the opening of the canal the water at Grafton was sluggish, had more or less grenn scum and moss, the current was not as swift and the water was more of an impure character. There are two doctors in Grafton. I cannot call to mind any case of typhoid fever among the fishermen in the last three or four years. I don't know of any cases that I have attended during the last three years that I could attribute to zymotic causes—that is, of typhoid character that could have been caused

2954 by drinking Illinois river water. Between here and Hardin I certainly know of fifty fishermen engaged in the fishing business. From a knowledge based upon appearance and a use of the water, I would say that the waters are much better than they were before the canal was opened and I mean by that, its appearance. It has a purer appearance.

CROSS EXAMINATION, By Mr. Jeffries.

2955 I have not noticed any green scum on the river now. It does not form now because the current is swifter. It is said now that the current is about six miles an hour. I do not think it used to be six feet an hour thirty years ago. At that time I used to cross over to Hardin and go back and forth in the same track where the canoe had parted the scum hours before. The year prior to the opening of the canal the condition was the same.

2956 The increase in the volume of water and this increased flow of the current is caused by throwing the water from Lake Michigan into the canal. The people at Grafton get their water from wells and springs.

RE-DIRECT EXAMINATION, By Mr. Todd.

Mr. Meysenburg has a pump with which he lifts the river water into a tank and I piped from his tank to my residence. I have used that water for five or six years for stock. I never have used it for washing purposes. I do not use it as a beverage

or for cooking. That water has no injurious effect upon stock. A family living close to me use it for domestic purposes.

RE-CROSS EXAMINATION, By Mr. Jeffries.

I suppose that tank holds ten or twelve hundred gallons. The water is pumped into the tank and allowed to settle; during hot weather we run one or two tanks full a day.

2957 That tank was in operation prior to the opening of the canal and the water in that tank is put to the same use now as it was when it was built, and no other use.

E. MEYSENBURG, Examined in chief by Mr. Todd.

Have lived in Grafton since 1867. Am sole proprietor of the Grafton bank and am in the merchandising business. I have always been fond of the river. I keep a boat of my own and have always spent considerable time fishing, hunting, etc., on the river. I live on the bank of the river. I am familiar with the river up from Grafton I should say 14 miles.

2958 Since the opening of the canal the water is not stagnant as it was previous to the opening of the canal. To my mind it looks much better. My well and cistern were flooded during this high water and I used water out of the elevated tank for domestic purposes during that time, which was since the opening of the canal. That water came from a well that was fed by the river. It was June 11th when the water flooded my well. I have used it up to the present time (July 14) but had my well cleaned out today. My family has used it to a certain extent.

2959 There has been nobody sick at my house. Prior to the opening of the canal the Illinois river frequently looked like a stagnant pool. There was a scum on it such as would form on a pond that had no current in it. There is now a decided current in the river. As to the fishing industry here, I have known as high as 12 tons to be shipped from here in one night. Fishing is queer business. The fish sometimes run for a week or two and then again the catch is very small, but the

fishing industry is quite an item here. The Illinois river is quite a prolific fishing ground.

CROSS EXAMINATION, By Mr. Jeffries.

The well that I said was fed from the river was fed through some source under the ground.

2960 The water that came from this well I am convinced is river water filtered through the soil. I did not go out into the river and dip the water up and use that water. When I say that the water in the Illinois river is better since the opening of the canal than prior to the opening, I base my opinion partly upon the fact that the water is clearer and free from scum and partly from the fact that I believe running water is better water than stagnated water. My opinion is that swift running water polluted 200 miles above where it is to be used, is good water to use.

2962 JOSEPH SPANLE, Examined in chief by Judge Johns.

Have been a fisherman since 1851. Live at Grafton at the present time. Have fished in the Illinois river since 1857 but I couldn't say much about the water in the Illinois river before the canal opened, either way. Sometimes the water got too low. It didn't smell much but it did get kind of still. There was no current in those days. It had a green scum on it in the summer, lots of it, sometimes. It was no good to drink at that time, that is in the part of the year when it was low.

2963 It was a natural color. I couldn't see no difference in the color much. Before the opening of the canal moss and slime got on our nets, some little moss yet comes once in a while but the current washes it off more. I have not drunk the water since the canal was opened. In the winter time when it was cold enough to drink, I have. The water looks more clear now than it was.

Q. You are a German and do not speak English very well?

A. Well, I used to come from France. They used to call me a Frenchman. The State used to belong to France where I came from, but now the Germans took it away from France.

CROSS EXAMINATION, By Mr. Jeffries.

There is a good deal more current now than there was before the opening of the canal. I live here in Grafton. I have a well at my residence.

2964 I don't use the water from the river at all when I am home, but when I am out I do use it sometimes.

DANIEL HEATH, Examined in chief by Judge Johns.

Reside at Grafton. Am a fisherman. Have been a fisherman for twenty odd years. Have fished in the Illinois river during this entire time. Before the opening of the drainage canal after the spring freshets in the summer time there was no current. The river was dead. It used to have a green scum on it just like a pond in the summer time. We used to

2964 drink it in the cool weather in the summer and fall. Before the opening of the canal there used to be a green scum gather on our nets. It would hang down in tassels. In the summer time when it was stagnated it would smell. Since the opening of the canal we have always had a current in there and the water always seemed to be purer because the current was in there. It kept the banks washed off—the current you know. I drink the water now in the spring and fall and winter —in the hot weather we don't drink it.

2965 Am acquainted with a good many of the fishermen on the river up as far as Kampsville. Since the opening of the canal there has been but very little moss on our nets. The slime that hung down in tassels is not so bad any more. I do not remember of the fishermen having typhoid fever since the opening of the canal. I cut ice nearly every winter for a week or so here at the mouth.

2966 The ice that I cut would be of Illinois river water. It seems to be about the same now as it was before the opening of the canal.

CROSS EXAMINATION By Mr. Jeffries.

My opinion is based altogether on the appearance of the water. There always is a great deal more current now than there was formerly. We always have a high current only when

the Mississippi is the highest and backs it up.

2967 I have a cistern at my house. We get the water out of a well but I haven't any myself. Only use the river water when I am on the river working.

GEORGE SEIK, Examined in chief by Judge Johns.

Live at Grafton. Am a fisherman. Have been a fisherman since 1892. Have fished in the Illinois river every spring. Before the opening of the canal the water in the summer time was a good deal like a pond. The current would leave it and a green scum would come over it. When we had a heavy raise, there would be a good deal of current in the river. The water would smell like stagnated water in the summer time.

2968 The water never smelt in the spring of the year but when it had this green scum on it it smelt like a stagnated pond. The water had a kind of milky color as near as I can tell. Before the canal was opened we drank it right along in the spring and fall. In the summer time we wasn't in the Illinois very much in the hot weather. If we should happen to be there and had no water we would drink it then. In the fall of the year there would be moss on the nets. Since the opening of the canal there has been more current, therefore I think the water is purer than it was before. I do not know that it is any better to drink. The water tastes cool and it must undoubtedly be better to drink because there is more current in the water. It is a purer water.

2969 When the river raises it muddies up and when it falls, it clears some, but whether that is the fault of the canal or not I do not know. There are 20 or 30 fishermen from my own place. I don't know of any typhoid fever among the fishermen in the last three years.

CROSS EXAMINATION, By Mr. Jeffries.

I don't know what typhoid fever is. I am not posted on the disease whatever. As I said I do not know of any one having it. By pure water I mean a clear running stream, I think is pure water.

2970 We use cistern water at our house most of the time. I do not use the river water all the time, only when I am on the river; I use it in the spring and fall. There is more current in the river now. The current lasts longer.

ALBERT FREIMANN, Examined in chief by Judge Johns.

2971 Live at Grafton. Have been a fisherman 19 years. Fished in the Illinois river during that time. Before the opening of the canal the Illinois river would be kind of stagnant during the summer season. When it got down low it was a kind of a dark black. In that condition it smelled like a pond or an inland lake. The moss and stuff would get on to our nets. We drank it in cool weather. Since the opening of the canal the water seems to be much purer than it was—more current I suppose, is the reason. I drink it since the opening of the canal during the cool weather. It seems like it is a kind of milky light color. In cold weather all the fishermen that I know of, drink it.

2972 No one that I know of has typhoid fever. I have cut ice here every winter that they cut it for over 20 years. I don't know as I notice any difference in the ice now to what it was before the opening of the canal. Moss hasn't as yet gathered on our nets since the opening of the canal. I have fished up the Illinois river 15 miles.

CROSS EXAMINATION, By Mr. Jeffries.

The water isn't exactly the same color as it was. I never paid much attention to the ice. Before the opening of the canal the water was of a rather dark color and since the opening it has a kind of a milky-like color. It looked like you might take a drop or two of milk and drop it in a glass of clear water—just changed about that much from clear water.

2973 Am a married man. Use well water. Don't use water from the river at my house, only use the river water when I am out fishing. By pure water, I mean water fit to drink—healthy—I suppose would be pure water. It seems that since the current has been there it was more pure than it was before.

It seems that there was more chills and fevers around town before than there has been since. It was kind of an ague fever I guess, it wasn't typhoid fever as I know of.

2974 I judge the drinking qualities of the water from its appearance.

WILLIAM WRIGHT CRANDELL, Examined in chief by Judge Johns.

Am a fisherman. Reside in Grafton. Have been fishing since 1896 in the Illinois river above Grafton. Before the opening of the canal, water in the Illinois river was stagnated, unless we had a head raise. It was dark in color. It didn't have a pleasant smell by no means. It affected the nets pretty badly. It covered them all over. It was mostly slime first. It would come on the net and hang down in pieces that long (indicating) as thick as your finger and then the moss would come and cover the nets so heavy you scarcely could lift them.

2975 It wasn't so good to drink then. I have fished there now since the opening of the canal, within the last two years, in April and up to that time the water was pure and reasonably clear, with the exception of the leads that would run into it, you know, and in heavy rains. There hasn't been any odor to the water since. The fishermen on the Illinois river who drink its waters have not had typhoid fever.

CROSS EXAMINATION, By Mr. Jeffries.

The water wasn't as good prior to the opening of the canal as it is now, because if you take a spring or a pool, if it hasn't an outlet and a stream to flow to, it is impure, and before the drainage canal we had no current in the Illinois river at this time of the year. We now have the last few years, all the year around, a right good current.

2976 Before the opening of the canal it was dark in color and now it is a kind of clear, milky color. Am a man of family. We use well water. Don't use river water at my house. My family doesn't use it.

CHARLEY JONES, Examined in chief by Judge Johns.

Live in Grafton. Have been a fisherman for about ten

years. Fished on the Illinois river more or less every year. Before the opening of the canal the Illinois river was generally dead water. Since the opening of the canal there is generally a good current and it throws off all that green scum and things of that kind.

2977 Before the opening of the canal there was no current and in taking up a net there was a kind of slime and sediment all over it. Since that, there hasn't been so much of it. Have helped to put up ice. Where there is a curent there is bound to be purer water and bound to make better ice. Before the drainage canal was opened the water had a smell. Since then it has none that I have noticed. The fishermen on the Illinois do not have typhoid fever that I know of.

CROSS EXAMINATION, By Mr. Jeffries.

We use well water at home.

2978 We don't use river water. Prior to the opening of the canal the color of the river was kind of milky. Since the opening of the canal I should judge the water would be better to drink. It would be purer. There is a current to drive that stagnated water off, that slime, etc.

THOMAS COCKSCHOTT, Examined in chief by Judge Johns.

Live at Grafton. Am a fisherman. Fished in the Illinois river every season for 20 years.

2979 Before the opening of the drainage canal, the Illinois river after the spring rise was dead. Now there is a good deal of current in it and has been for the last three years. Whenever it comes a raise it is a dirty color, it is muddy and dirty. It is clearer now than it was before the opening of the canal. There is more the color of lake water in it when there is no raise. I drank it before the opening of the canal. In hot weather, when it was warm, it was pretty tough to drink. It is better to drink now than before the opening of the canal. It is clearer. The moss on our nets before the opening of the canal was worse than it is now. I have engaged in put-

2980 ting up ice. I believe it is clearer now than it was before the opening of the canal. Fishermen on the Illinois river haven't had typhoid fever either before or since the opening of the canal that I know of.

CROSS EXAMINATION, By Mr. Jeffries.

At home we don't use the river water. We use a cistern.

2981 MARTIN GILMORE, Examined in chief by Judge Johns.

Live in Grafton and am a fisherman.

2982 I have fished in the Illinois river every year for 12 years. Before the opening of the canal the Illinois river at certain seasons the water was dead. There was no current. It had a scum on it. Since the opening of the canal there is a pretty fair current in there all the time. We never see no scum up there now. When the water is down pretty low it is clearer than it used to be, but when there is a rise in it it looks just the same as ever. Before the canal was opened there was times that slime and scum smelled very bad, when the water was dead and had no current. We seined up there one year when there was no current and we couldn't seine over three or four hours. If we would catch any fish we would have to come down here and ice them. They would spoil right away, but since the opening of the canal it seems like the fish live better. I have drunk the water both before and since the opening of the canal. The water seems to be more clearer now than it used to be and it is clearer.

2983 I never heard of fishermen in the Illinois river having typhoid fever. I have never known of but one fisherman to die around here that I can remember and he was an awful old man. Have engaged in putting up ice and it seems to me the ice is clearer than it used to be. There aint the dirt in it and there aint as much drug in it as there used to be.

CROSS EXAMINATION, By Mr. Jeffries.

There is a good current in the river now. Before the opening of the canal there was times there was no current unless there was a raise out of it. There is always some current now.

When I say the water is better now than it was before I say it is clearer looking, it aint stagnant, it is running water.

2984 WALTER RICHEY, Examined in chief by Mr. Todd.

Am a fisherman. Live at Grafton. Have lived here 23 years. Have been engaged in fishing 14 years. Am acquainted with the Illinois river from here to 12-Mile Island, which is 12 miles from here. Before the opening of the canal there was a slight current in the Illinois river and it was stagnant, like a pond most of the time in the summer and fall. There was a green scum in low water when the current was slack and where the water would flow away from the mud, it smelled bad. If we put fish in a float box then, they didn't seem to live as well. There was no current and it seemed like they were softer. They didn't live as well in the nets.

2985 I think the water is purer now; clearer, more pure than it was. It is a different color. I don't think it gets green now in low water time. I haven't seen it that way in the last couple of years. The opening of the drainage canal and the turning of the waters of Lake Michigan into the river has put the river in better shape and I think the water is in better shape. It is more purer than it was. I always drink the water in the cooler season of the year. We always carry water with us in warm weather. When we carry water we don't carry ice. About 30 or 35 fishermen fish upon the Illinois river from Grafton. I don't know of any fishermen having typhoid fever from drinking the waters of the Illinois river since the opening of the canal. I don't know of any fishermen having had typhoid fever during the last three years. I don't know that the water of the Illinois river which I drank had any effect upon my health.

CROSS EXAMINATION, By Mr. Jeffries.

2986 Am a married man. Use well water at my house. My family uses well water at my home but they use river water when we are on the river. I live on the river part of the time. The water is a little muddy now. It is more muddy when it is raised than it was before the opening of the canal. It has a milky color. It used to have a kind of green moss on it.

2987 Pure water is running water, water that looks purer, I think it is more pure than water with a green scum or that looks kind of green. That is my reason for saying it is better water.

R. A. SAWYER, Examined in chief by Mr. Todd.

Live in Grafton. Have been a fisherman for ten years. Fish in the Illinois river every spring. I think the water is in better condition now than it was before the drainage canal was turned in.

2988 Before the drainage canal was turned in, it was like a lake or a pond. Green scum on the water and moss all over the shores. The water was really a dark green and today the water is clearer and purer looking than it was before. I prefer drinking it now better than then, as far as I am concerned. I drink the water in the spring of the year. Haven't experienced any ill effects from the water since the opening of the canal. The fish live better today when we take them out of the net than they did before. It don't form a scum on the nets like it used to. I never knew but one fisherman to die since I have been in Grafton and he died with the heart disease. He was about 65 or 70 years of age.

2989 CROSS EXAMINATION, By Mr. Jeffries.

Am a married man. Use well water at my house. I say the water is purer now than it was before the opening of the canal because it looks purer and clearer when you look at it. I have drunk the water both before and after when it was cold. That is the only way I can tell it is better now than before. There is a current now. Before the opening there was a current when we would have a rise, but the majority of the time there was no current in the Illinois.

ALBERT LEE, Examined in chief by Mr. Todd.

Live at Grafton, am a fisherman.

2990 Have fished about 15 years. Most of the time I was fishing on the Illinois and part of the time in the Mississippi. Before the canal was opened, the Illinois river water, when the water would get low, it would get very stagnated and would

get a kind of green scum, and would smell very bad. When we were seining up there in the fall of the year, it would be nearly impossible to keep our fish alive. Since the opening we have always had a pretty fair current in the river and the water has been more clear except when there would be a rise in the river, and it was better water and more pure. When I am out fishing, I drink the water but when the weather gets so warm we quit drinking it. We generally take a jug of water with us and then when we get up to the club house we fill the jug there. I do not know but one fisherman that has died in the last 12 years and he died of heart disease. The fish live better now than they did before.

2991 CROSS EXAMINATION, By Mr. Jeffries.

There is a current in the river now. Not so very much. It seems to be slackening off a little. There is no green scum on the water. Before the opening of the canal the river was like a lake, sometimes there wasn't any current at all. I say the water is better now because there is a current in the river and there is no scum on the water and it doesn't smell and it is better to drink than it was; then, you couldn't drink it at all and the fish wouldn't live in the water either. Am a married man. Don't use river water for drinking purposes at home now, but up to a year ago we did.

2992 When I said the fish didn't live in the water I meant that it seemed like the water was so foul that when you would take them out, and in handling them and putting them in the box or float net, just that little time out of the water would kill them.

(AT HARDIN, ILL.)

2994 CHARLES FLAMM, Examined in chief by Mr. Todd.

Am an insurance agent. Before last fall was county clerk of Calhoun County. Live in Hardin. Have been acquainted with the Illinois river at this point (Hardin) for the last ten years. Hardin is about 41 miles above the mouth of the Illinois. Population is about 500.

2995 In my opinion the water in the river prior to the opening of the drainage canal wasn't as pure as it is now. Prior to opening of canal the low water on the river on the east side was covered with vegetation and it looked to me as if the water was very impure. There was a scum on the water. It was a greenish scum and when you passed through it with a boat it left a trail. You could notice it for some time afterwards; that is when the river was rather low; low water; during the summer months. Since the opening of canal it has a better current and this scum no longer appears. I have drank the water since the opening of the drainage canal. I did not drink it before. About 12 or 15 fishermen are engaged in fishing at this point in the river.

2996 I do not know of any one who had typhoid fever or who died from typhoid fever in the last two years at this point. In my opinion from the appearances, the water has improved since the opening of the drainage canal in January, 1900.

CROSS EXAMINATION, By Mr. Jeffries:

My opinion is based entirely on the appearance of the water. I say that the water is better since the opening of the canal than it was prior thereto for the reason that the green scum that formed on the river prior to the opening does not form since the opening, and because of the creation of the current caused by the opening. Am not a physician. Don't make it a business of looking after the health of my people. We use cistern water at home. Hardin has no water system—only wells and cisterns.

2997 EDWARD ATHY, Examined by Mr. Todd.

Live in Hardin, Calhoun County, Illinois. Lived here about 20 years. Work at carpenter work. Have been acquainted with the Illinois river since I have lived in Hardin. By the appearance of the Illinois river it has improved since the opening of the canal. Before that time the water was inclined to be milky looking and muddy, and a scum over the river that was noticeable by every one. I cannot say there was any odor to the water. During the time this scum was over the river, row

boats left a clean furrow over the river. I have crossed the river many a time and could see clear across, or half across. Since the opening of the canal I have observed a more lively current, a better movement of the water and I have observed less of this scummy looking filth on the top of it than before.

2998 My judgment is only from appearances and the water appearing clearer and cleaner, I should say it was purer. Have not noticed any odor in the water since the opening of the canal.

CROSS EXAMINATION By Mr. Jeffries.

I am not on the water a great deal. I am not qualified to judge only by appearance. I think a better movement of the river carries the scum away. It did not give it an opportunity to form. I don't know whether the sewage matter from Chicago gets down this far. My opinion is the waters have been improved by the increased flow. I have not observed here anything in the Illinois river that would lead me to believe that the sewage from Chicago was present in the waters of the Illinois at this point.

2999 NATHANIEL BULL, Examined in chief by Mr. Todd.

I live in Hardin. Have lived here six years. Have lived in the county since 1860. Am a farmer. I have been slightly acquainted with the river for the last 10 or 15 years. Not traveling around on the water but living along the river.

3000 Prior to opening of canal river was like a pond—there was a scum over it—you could see if anything had passed through it. There was an odor to it. Since opening of the canal I have seen none of that to amount to anything on it. It appears to have a current. Haven't noticed any odor at all since the opening of the canal. With a good current in the river since the opening of the canal, it certainly has improved--taking that away and making the water pure.

MR. JEFFRIES: Move to strike out question and answer for reason witness has not qualified himself to testify on that subject. (Same objection is made to all these witnesses.)

CROSS EXAMINATION, By Mr. Jeffries.

There is no scum on the water now because there is a better current, I guess. Never had the water examined. Just by appearances as I passed along it.

3001 There is a big difference in the current. It is a better current now than before, it was a pond—you could throw a chunk in and it was pretty near as apt to float up stream as it was down. I drink well water. Two years ago we used Illinois river water—the dry season. I hauled water from the river; when I couldn't get any other water—we don't use river water when we can get well water.

M. E. FISHER, Examined in chief by Mr. Todd.

Am merchant, reside in Hardin. Have lived here 35 years—all my life. Am acquainted with the Illinois river. Got acquainted by being on it all my life. I fish with a hand line. Before opening of canal so long as river was down low and green grass growing in it and scum all over it, it made a smell.

3002 When a skiff went through it left a track through the grass and scum. Since the opening of canal the river is up higher and clearer and a swifter current; better water. Drank waters of the river before and after opening of canal. Think the water is in good condition here now. It is better since the opening of the canal. The river is clearer and swifter current. About 10 or 12 people are engaged in fishing business at this point.

3003 Don't know of any deaths from typhoid fever in this locality. Am acquainted with all the people in this town. Every body knows each other here and each other's business.

CROSS EXAMINATION, By Mr. Jeffries.

Have a well or cistern at our house. Use cistern water at home. No water system in town. Made no examination of the water in the Illinois river prior or since the opening of the canal. All I know about the water is what I get from appearance. Opening of canal has increased current very much more. Don't know whether the water contains deleterious substances now or not.

3004 ABNER POOR, Examined in chief by Judge Johns.

Live in Hardin and fish for a living. Have been a fisherman about 28 years. Fished here prior to 1885. At that time the river along in summer and fall, I don't know what you would call it, but I would call it poison; more poison than water. There was a green scum on it; no current in it nor nothing. You could put a net in the water and raise it up you know and it would just be hanging in tags.

MR. JEFFRIES: Motion to strike out answer.

Was not aware that in 1885 the city of Chicago pumped its sewage into the I. and M. canal and continued that until 1900.

3005 The water is more pure and better now than it was in 1885 at this time of the year, it has been in the last two years. I know the water is better now than it was then. Before 1900, for 15 years, the water in the Illinois river was substantially always in the same condition. It was low, no current, and most awful dirty and nasty. This dirt and nastiness come from the stagnated water, as far as I know—it couldn't come from anything else but the stagnated water, that I know of; it was just like one of these ponds. In the water if you cut a hole in the ice a kind of nasty green scum would come up in that hole and you would pull a net up and it would just be tags hanging all over it. Those tags were filth from the dead water. Lots of fish died under the ice. I have drank the water ever since I have been fishing. I never pretend to take spring water or well water with me at all.

3006 When I would be seining and pulling the sein where it was shallow and this grass growing in it all rotten, it smelled pretty bad there. Since the opening of the canal the water has been more pure and it tastes better too. We don't have any more moss and filth in the river since that. We don't smell it any more, the current takes off the filth and smell.

3007 My fishing operations have extended from 12-Mile Island to Kampsville. That is about 16 miles by river. I never

knowed a fisherman along the Illinois river to have typhoid fever. As a general thing the fisherman is the hardiest thing there is along the river. The fishermen, the majority of them, generally drink the river water. That is I can say that much for the fishermen around here; none of us carries water with us no matter how far we go.

CROSS EXAMINATION, By Mr. Jeffries.

My fishing trips have made me acquainted with the Illinois river for a distance of about 18 or 19 miles. I am 61 years old and have been fishing right here for 28 years.

3008 We had no current at all before the canal was opened. When a skiff got loose it was as apt to go up stream as down stream. Just like this spring when the Mississippi was backing the river up. I say the water is better now than it was before the opening of the canal for the simple reason it tastes better now. Better fishing now than there was then. Water is deeper and there is more of it. Before canal was opened you could take a tin cup full of water and let it set and there would be a thousand little worms in it, just like you get in one of these ponds, and dip it up, like wiggle-tails. That is not the condition now.

3009 RE-DIRECT EXAMINATION, By Judge Johns.

Before the opening of the canal fish lived 24 hours in live boxes. Now you can keep them for four or five days—I kept them that long last summer. Fish are livelier and appear better—they have got more life about them than they had before and there is more of them too.

DR. P. C. BERRY, Examined in chief by Judge Johns.

Am a retired practicing physician. Practiced medicine in Hardin and vicinity for over 30 years. Retired from active practice about 4 or 5 years but am still doing office practice. When in active practice I covered sometimes 30 miles south of Hardin and 15 miles north.

3010 Prior to opening of canal there seemed to be a scum on the river in summer time and no current and even in best season of year you could smell it; there was a sort of stench

on it and water did not appear to be clear. I attributed the stench more to decayed vegetable matter in the river and washings from these creeks along the river. Since opening of canal it seems to be better—clearer and purer. I consider the water now purer and better for consumption by the people.

3011 I consider the well water all river water seeped into wells. To my knowledge we have had no case of typhoid fever here; we have had cases of typhoid-malarial fever. Fishermen do not have typhoid fever that I know of. Have practiced medicine among them as well as among other people. When in active practice I generally had the largest practice of any physician in Hardin in those days.

CROSS EXAMINATION, By Mr. Jeffries. (Similar to preceding witnesses.)

CHARLES H. LAMAR, Examined in chief by Judge Johns. Editor and publisher of Calhoun Herald.

3013 Have lived in Hardin 8 years and in vicinity of Illinois river all my life time, 40 years. Lived 3 miles north of Hardin, about 1 mile west of river, before coming to Hardin. From boyhood I don't think there has been a year passed but what I have had occasion to fish and swim and hunt around the Illinois river. Prior to opening of canal water was less; not so rapid current and at times stagnant; in low water much so; considerable vegetation found in river; had an odor in summer. Attribute odor to grass growing in river and to green scum found upon water. Used the water for drinking and domestic purposes when on the farm.

3014 Water is now clearer and fresher. Don't know of a case of typhoid fever from using the water before or after opening the canal.

CROSS EXAMINATION, By Mr. Jeffries.

Never examined the water, only in a casual way in rowing on it or bathing in it. What I say in reference to it is obtained simply from my observation. People in town drink well or cis-

tern water; use it in their homes, and I do. River water is not used for domestic and drinking purposes by people in town.

3015 G. A. WILLIAMS, Examined in chief by Judge Johns.

Live at Hardin. Practicing physician. Practiced 22 years at Hardin. Been engaged in the general practice among the people. Prior to opening of canal water was at times stagnant; during summer had an odor arising from no current and stagnant condition; odor arose from decaying vegetation and perhaps sewage too. Since opening of canal it is much better—much improved.

3016 I suppose people living along river use water for domestic purposes and drinking to some extent. Prior to opening of canal there seemed to be a good deal of typhoid fever among people living along the river. Since opening of canal we haven't any cases, at least I haven't had any. Ice taken from river is clearer and better ice since opening of canal than it was previous.

CROSS EXAMINATION, By Mr. Jeffries.

There were as many typhoid cases as a dozen, in 15 or 20 years. Since opening of canal I haven't had any cases;

3017 other physicians may have had. Some of the cases prior to opening of canal were genuine typhoid and others of typho-malaria. Never made a chemical or bacteriological examination of the river. Know nothing of its qualities except from observation.

CHARLES E. COOKE, Examined in chief by Judge Johns.

Am implement dealer and agent for Eagle Packet Company. Lived in Hardin about 19 years. Been agent for Eagle Packet Company about 14 years. That company is running a line of boats on the Illinois river. There is great deal more

3018 water now in river than prior to opening of canal; much more current and no odor at all now. Prior to opening of canal there was odor and it was very bad when the wind was from the east, very offensive, that is, in low water.

There is not much ice put up at Hardin since dam was put in at Kampsville. When we could get good ice, the ice has been much clearer. I don't know of any people using river water being sick, complaining any, only rheumatism, which is always the case on a river.

3019 M. J. PARKER, Examined in chief by Mr. Todd.

Live in Hardin. Lived here since 1873 with exception of five years I was on my farm in Jersey county. I run on Illinois river for 4 years, steamboating, from St. Louis to Montezuma and part of the time as far as Naples. It is 32 miles to Montezuma and we call it 50 miles to Naples. Am in orchard business at present.

3020 Quit steamboating in 1899 but have been on river hunting and fishing every season. Before opening of canal it was a very sluggish stream and it looked like there was an accumulation of moss and grass and the stench was pretty bad at times, especially in warm weather and low water; the water had a kind of a greenish appearance and very little current. There was considerable of a scum on the water at times, especially when we had a continued drought, and low water; it would be a good deal more than it would be in the wet season; when the water was coming in from the draw, that is

3021 after heavy rains, it would clear it up considerable.

Since the opening of canal I consider there is quite an improvement in the appearance of the water; it looks clearer and purer and we have got a decidedly better current, and it tastes better; it is not so sickly and such a flat, filthy taste. I have drank the water since the opening of the canal. Early in the year the water is just splendid, but during this season of the year the water is too warm; take the ice along it makes it very nice. When I go fishing I take ice with me and drink Illinois river water. I don't think I ever experienced any deleterious effects from the use of the water.

It is 100 per cent better now than before the opening of canal. I base my conclusion on the condition of the water and the appearance of it, and the life and the current we have and

the tasting of it. Of course, I don't want it understood that I am an expert on this, but then it was in a fearful condition prior to the opening of the canal, especially in hot weather and at low stage.

3022 CROSS EXAMINATION, By Mr. Jeffries.

When I say that the water is better now than it was prior to the opening of the canal I just judge from its appearance and the current and the stage. I am not scientific enough to explain whether there is any deleterious substance in the water now or not. The scum and green matter and substances that produced the smell, before the opening of the canal has disappeared to a great degree. I attributed the disappearance to the current and to the stage of water and flow which we have now compared to the river here prior to the opening. Don't use Illinois river water for domestic and drinking purposes. We have fine wells in Hardin, and cisterns; we don"t use any river water at all, without it flows in our wells here—it might seep in, you know.

3024 G. B. CHILDS, Examined by Judge Johns.

Live in Hardin—have lived here all my life with exception of my school days and about 5 years in St. Louis. Have become familiar with the Illinois river by living on it; rowing on it, hunting on it, and living near it, right on the river bank here. Prior to opening of canal I have seen it in the summer during extreme low water when the weeds were growing thickly in it on either side of the channel; it was a greenish cast and full of greenish sediment and I have seen it so low that we have had no boats at all on it. It had an odor. The odor

3025 was offensive. Attributed the odor to the grass and moss on it. Since opening of canal so far as my observations have gone, it is clearer and the water seems to be better and more volume. I have seen no grass and sediment since the opening of the canal. Opening canal has raised the river about five feet. Some people drink river water since opening of canal. Health has been better since opening of canal.

3026 CROSS EXAMINATION, By Mr. Jeffries.

Use cistern or well water at home. In my statement that the water is better I judge from appearances and I have drank it, being out fishing and taking ice with us. We have a more rapid current. Last spring there was no current. The river was higher. I mean it was high on account of the backwater of the Mississippi. Aside from the time when the backwater from the Mississippi came up, there has been no time that there was not a current since the opening of the canal.

3027 Have never had the water examined chemically or bacteriologically. I don't know what its ingredients are. Don't know whether it contains Chicago sewage or not.

DR. S. FLATT, Examined in chief by Judge Johns.

Am physician and reside in Hardin. Have been practicing physician at Hardin five years. Prior to opening of canal Illinois river was muddier in color, less in quantity; current slower; odor more disagreeable. The odor was due to what is generally termed stagnant water.

3028 There was vegetation in the river prior to opening of canal. There are quite a number more fish in the canal now and the fish all seem to be in good condition. The fishermen on the Illinois river drink the water of the river. There has been but little typhoid since I came here. I had 3 cases I think prior to and 2 since opening of canal; though one of them was not on this river; one was across towards the Mississippi river. Since opening of the canal the health of the community has been good—exceptionally good.

MR. JEFFRIES: Move to strike out question and answer for reason there is no evidence showing that the people use the water of the Illinois river for drinking purposes and domestic purposes.

CROSS EXAMINATION, By Mr. Jeffries.

I never examined the water in the Illinois river. When I say it is better now than it was prior to opening of canal I simply judge from its appearance; from its color; it was not so thick and greenish looking; it is clear and a better smell to

it. The people here in Hardin generally use wells and
3029 cisterns; two years ago they used water from the river on account of drought. The people throughout the country generally used river water two years ago. The current of the river is better; it is three times what it was prior to opening of canal.

GEORGE L. ADERTON, Examined in chief by Judge Johns.

Am county clerk of Calhoun county, Illinois. Reside in Hardin. Lived here since 1894. Have fished great deal on
3030 river with rod and line. I noticed prior to the opening of the drainage canal the water was sluggish and not so clear as it is at the present time, or after the opening of the canal. There seems to be more current and the water has generally a better and clearer appearance since the opening of the canal. Never to my knowledge have I noticed that it had any odor. I have a pretty tolerably extended acquaintance around here throughout the county, bordering on the Illinois river. We have used river water before and since open-
3031 ing of canal, but not for cooking or anything like that; we have had it for laundering and such as that. I have drank the water while out fishing and I have known others with me, but to make a general statement of it, I couldn't say as to that. I think the general health of the people is about as good now as it was prior to opening of canal.

CROSS EXAMINATION, By Mr. Jeffries.

We use cisterns and wells for domestic and drinking water. I couldn't say that my neighbors do; sometimes their cisterns go dry and they have got a good many public wells in town. Perhaps they use more well water than river water, because our town is well supplied with wells, and as to saying positively whether they do or not, I couldn't do it.

3032 Prior to opening of canal we had no current scarcely. We have got a good current now at all seasons of the year except when the water of the Mississippi backs up. I don't think the river water is used for cooking to any great extent or

drinking except by the fishermen that are out in the river. Still, there is a good many people that use it ocasionally. I am one of them myself. They do not make a practice of it though.

3033 Never had the water in the river examined either chemically or bacteriologically before or after opening of canal.

T. J. SELBY, Examined in chief by Judge Johns.

Lived in Hardin since September 16, 1884. Was member of 57th Congress. Commenced practicing law in Hardin in 1875; I lived then at Jerseyville. From Hardin to Grafton by river is 30 miles.

3034 Prior to opening of canal, in high water time we would have a good current. In summer season when the water was lowest there was very little current in the river at this point anyway; it resembled very much a large pond; I have seen it filled with grass, particularly on the eastern side of the river at this point. The color of the water I am not positive about that, It was not absolutely clear nor yet really muddy so far as my recollection goes. As to odor, sometimes that would be pretty bad in the fall season, perhaps in September, owing to this decaying vegetation being in the river. That was not always the case, however; when the river was high why the conditions would be different. The water then would be muddy and the current stronger and it would sweep away this accumulation of stuff in the river. Our low water period is I would say from the first of July on into the fall. Since opening of canal grass and vegetable growth is now totally absent. 1901 was a very dry year and we had very fair water. The water may be clearer now, but I would not be positive about that. From the general appearance of the river itself it looks probably clearer, but I have not inspected it for the purpose of ascertaining. The health of the community since opening of the canal has been good. I don't know of any time when it has been particularly bad, however.

3035 CROSS EXAMINATION by Mr. Jeffries.

I only state from general appearances. I have been on the river frequently, crossed it and fished in it and noticed it; drank out of it, before and since opening of the canal. My idea is if there is any difference I would say it is clearer now than it was at low water times before. That is simply an ocular observation; all I know about it is from observation; I have had no examination made either chemically or bacteriologically. I am no bacteriologist; I don't know of any ill effects from the use of the water or haven't heard of any. I can't say whether or not it does now or did prior to opening of canal contain deleterious substances so far as I personally know. If it does there don't any of us know.

3036 People in Hardin use both well and cistern water. People living in shanty boats get it from the river. I have seen them dip it up in buckets. Since opening of canal we have a better, stronger current—a great deal stronger. I don't know what the per cent would be, but I would say considerable.

ELMER E. WILLIAMS, Examined in chief by Mr. Todd: Cashier of Bank of Calhoun County. Lived in Hardin since February, 1899.

3037 From February, 1899, to January, 1900, we had a swimming club and would go swimming down at Rocky Bar about a mile below. The water got so foul along in July and August, about August I guess, that we couldn't go in swimming any more. There would be a green scum on the water and a very foul odor; very turbid. And it was very low, too. We could observe the odor from where we lived; we lived about two blocks from the river and the street runs right down to the river with no buildings south of it; it was very offensive. Since opening of canal there was no green scum formed and no perceptible odor like there was the previous year, and that condition has been, I think, improving for the better as to the sanitary condition and clearness of the water and less foul. The sanitary canal waters have purified the Illinois river at this point; the drainage canal has purified the water.

3038 CROSS EXAMINATION by Mr. Jeffries:

Am not an expert on the sanitary condition of water. It is just my general observation, that's all. Never had this water examined either before or after opening of canal.

Don't use water of Ilinois river for drinking and domestic purposes but we use cistern or well water. I have drank the Illinois river water, though, when I was out fishing. My neighbors have cisterns or wells, but then for drinking purposes they most all use water from the town pumps here.

3039 I don't know whether or not the deleterious matter contained in Chicago sewage comes down this far.

Q. It may or may not so far as you know?

A. No, I do not konw.

WILLIAM McNABB, Examined in chief by Mr. Todd:

Am druggist. Been living in Hardin about six years. Have been on Illinois river a good deal boating and have been fishing. The water in 1899 was very low, the stage of the water here, scarcely any current and the condition of the water was not as good as it is now by any means; there was a scum over the river during that year, a green scum. There was an odor to the water. Since the opening of canal we have had

3040 a better stage of water, a good current, and we have no scum over the water and there is scarcely any perceptible odor now. The water is a good deal better than it was before the opening of the canal. My observation leads me to that conclusion. I am the only druggist in town. I disremember of a case of typhoid fever in town since opening of the canal. There has not been as much malaria in this community since as existed before opening of canal. I know the chill tonics and preparations for that complaint; we haven't sold since the opening of the canal one-third or perhaps one fifth as many as we did before.

CROSS EXAMINATION, By Mr. Jeffries.

3041 I board and don't use water from Illinois river. I never made an examination of the water for sanitary purposes. I don't know whether the deleterious matter contained in the

sewage that comes from Chicago is contained in the water here at Hardin or not. Not from a bacteriological standpoint. I never examined the water in that way. Only of course from seeing it that I know, and the changes. I don't know anything about the ingredients of the water. It may contain deleterious matter and it may not so far as I know.

3042 (See re-cross examination of this witness.)

3043 L. M. DAVIS, Examined in chief by Judge Johns.

General merchant. Lived on Illinois river since 1855 except five years I was in army. Prior to 1900 Illinois river was less current and to my judgment a great deal more odor and so far as the use of that water for domestic purposes—I know but little about that; I don't know who uses it.

3044 I attribute the odor to stagnation; lack of current would be my idea about it. Since the opening of canal I can't say as I see a great deal of difference in the color of the water. There has been no scum on it and I haven't noticed any odor. Am pretty well satisfied that the health of the community has been equally as good as it was prior to opening of canal. Prior to opening of canal have seen the water very low. 12 or 13 years ago the waters got so low they got men at a point 20 or 25 miles north of here to go in with plows and scrappers to make a channel for a boat to go through. In 1901 we had no rain from June to November. If in that time the waters of the drainage canal had not flowed through the Illinois river, it would not have been navigable with anything larger than a skiff.

3045 CROSS EXAMINATION, By Mr. Jeffries.

In my statement that the water is better since the opening of the canal I am speaking from observation only. I use well or cistern water. I do not know whether the river water contains deleterious matters or not from experience. It is a stronger, swifter current now. The people in this locality use well or cistern water to a great extent. Almost exclusively outside of the fishermen.

WILLIAM U. MORTLAND, Examined in chief by Judge Johns.

Postmaster. Have lived in Hardin approximately 37 years. Was born and raised here. Have always lived within 500 yards of the river. Know nothing about chemistry but
3046 what I know about the Illinois river is from general observation. Have fished more or less with hook and line and have been in bathing frequently. Prior to opening of canal condition of river varied with the years. It was something in the nature of stagnant pool; water was covered in summer with yellow scum; apparently little current and very strong odor. Varied in different months. When weather got warmer it was stronger; August was especially bad. Great deal of vegetation; what we call commonly buffalo grass. Grass was everywhere here. I should judge odor was from vegetation. Since opening of canal from general appearances the current is stronger and water clearer and comparatively little if any odor from the water and absence of this buffalo grass. A few years ago there was more malaria than there is today. Whether it can be attributed to the difference in condition of water or not I can't say.

CROSS EXAMINATION, By Mr. Jeffries.

Don't know whether water contains deleterious matters or not. Don't use the water. Current is much swifter now than it was before. I only judge from boating I have done and swimming occasionally. I presume water flows now with a regular current at all seasons of the year except when the back water from the Mississippi interferes. It had a current prior to opening of canal—very little of a current before; considerable of a current since. Don't know whether deleterious matter from the sewage of Chicago reaches this point or not.

3048 JEFFERSON WELCH, Examined in chief by Judge Johns.

Am a fisherman. Have been in that business 21 years. Fished in Illinois river mighty nigh all the time. Of course I get over in the Mississippi sometimes in June or July, but then I fish kind of steady here. Fish with nets all the time.

Fish about 18 miles north and about that far down the river. Prior to opening of canal Illinois river was low in summer, full of moss and no current. Moss covered the nets; green moss. Would have to take it off with my hands; sometimes let it dry and knocked it off. Don't think the fish were as good as they are now. Haven't in the last few years seen dead fish along the banks like I used to see. Since opening of canal, water has been more pure, more current and there was not near as much sickness; wasn't near as much fever and ague along the banks or low-lands as there was before.

3049 Condition of the fish is better. They live longer in live boxes if you keep the live boxes in the current. As a fisherman I drink the waters of the Illinois river. The drinking qualities of the water now are better than it was; more cooler, the water drinks better. Fishermen along the Illinois river generally drink its waters while they are fishing. Don't know of any typhoid fever among the people drinking the Illinois river water since the opening of the drainage canal. Have been engaged somewhat in assisting in putting up ice. It seems like to me the ice is more clearer than it was before, more solider and more bluer than it was before.

CROSS EXAMINATION, By Mr. Jeffries.

We have more current now than prior to the opening of canal. Before opening of canal we had a very slack current in the summer time and of course if we had a head raise, then there

3050 was a current. We have a pretty fair current now all the time. I live in a house a mile and a half north of here. I have a well and cistern and use well water for domestic purposes.

WILLIAM MORTLAND, Examined in chief by Mr. Todd.

Farmer and fruit grower. Live in the corporation here of Hardin. I was county judge and member of legislature in 1881 and 1882. Have wood-boated on the Illinois river. I

3051 came here in 1848 and been here since. Prior to opening of canal I have seen this grass growing all the way except about 100 feet of the channel that wasn't covered with grass;

I have seen cattle and hogs grazing on it, and I have seen it here when we couldn't get a boat; when we couldn't get our freight loaded and I have seen it with a green scum all over it; it was unhealthy. It is a good deal healthier here since the canal was opened and I think the water is much better than it used to be.

CROSS EXAMINATION, By Mr. Jeffries.

I say the water is better than it used to be because there is not so much sickness here as it used to be and I am satisfied it is healthier than it used to be. That's my opinion. I have wells and cisterns on my farm and use them for domestic and drinking purposes. Some of my neighbors are supplied with wells and cisterns, and those who do not use the town water.

3052 The reason I have for believing the water is better since the opening of the canal is there is more current than there used to be and there is no green scum on the water like there used to be and there is not so much malaria as there used to be. Don't know whether the water contains any deleterious matter. Don't know anything about the ingredients of the water.

(Kampsville, Ill., July 16, 1903.)

C. B. BRAKEVILLE, examined in chief by Judge Johns:

Live at Kampsville. Am a fisherman. Have been fisherman all my life. I fished at Copperas Creek Locks, Havana, Meredosia, Pearl and Kampsville.

3053 At times wastn't as much water in the Illinois river prior to opening of canal than there is now. River sometimes became stagnant, it would be all green on top. To a certain extent there was an odor in the water, came from the vegetation. There used to be a good deal of moss and slime on our nets. Since opening of canal have never seen it smell. There isn't any more grass and weeds than there ever was. To best of my knowledge the water is clearer than it ever was; it clears up a little quicker. The fishermen as a rule drink the

water of the river. I guess there hasn't been a day in ten years but what I have drank some of the water; every day that I have been on the water. Am pretty well acquainted with the fishermen along the river.

3054 The fishermen do not get typhoid fever very bad; you hardly ever see a fisherman sick. Never heard of typhoid fever among the fishermen since the opening of the canal.

CROSS EXAMINATION by Mr. Jeffries:

I live in a boat all the time. We have a good deal stronger current than before the opening of the canal. The water is not clearer at all times of the year now; when it rains it muddies up but it clears up much quicker than it used to I think. Whenever a fair sized flood comes, the water gets just as cloudy and muddy now as it did prior to the opening of the canal, for a short while.

3055 I don't know what has become of the grass and moss growing in the river. There is a pretty fair current here now which continues over the dam.

There is a good current from Beardstown to this point. There is a pretty fair current from here to Grafton. There has been a good current in the river ever since the opening of

3056 the canal. Prior to opening of canal there was no current above this dam at all. I don't know whether the water contains certain substances that are injurious to health if used for domestic purposes. My only reason for believing that the water is better is because there is some increase in volume and a stronger flow. Am out on the river every day and a part of the night.

3057 I never paid much attention to the sickness in this town and around the country.

EDWARD HEATON, examined in chief by Judge Johns:

Live at Kampsville Locks, and am fisherman. Have been fisherman for 42 years. Commenced fishing at Chillicothe; fished at Peoria, Beardstown, Meredosia, Montezuma, Bedford and Kampsville. From the time the government locks were

put in the river until we opened the canal, our low water got very stagnant, dead and bad. In winter time when we were setting nets the smell that would come out from the ice we couldn't stand at all; a sort of a gas. First observed that at Bedford and Montezuma; the two towns are right close together.

3058 It was either in 1893, '94, or '95 it killed all our catfish. In summer it had an odor or smell; here at the dam anybody could notice it all summer long. We would have moss and slime on our nets in low water just the same as we have it now-days. You couldn't notice any difference in the fish. In live boxes the fish didn't live at all before in low water; we didn't have current enough to give them fresh water. They live middlin' fair in live boxes now. Have assisted in taking ice from the river. We get the ice a good deal clearer in some places, but we have got so much current it gorges together and we don't get as good ice now as we did before when we could catch dead water. I drink the water. There is very little typhoid fever that I have ever seen during all the time that I have been on the river. The fishermen generally drink the waters of the Illinois river and you don't find as many sickly fishermen as merchants.

3059 CROSS EXAMINATION, By Mr. Jeffries.

Live in a house. Get water for domestic purposes from public well. Am familiar with the river for 160 or 170 miles up. The water was stagnant and still and void of current from this to Henry Lock, about 189 miles up, prior to opening of canal. Since opening of canal I have only been acquainted with river for 10 miles up, and 8 or 10 miles down.

3060 The difference in the current or flow of the river is about one-half. There is a good current now. Opposite Kampsville it is about 2 miles per hour. This point is one mile and a half above Kampsville dam. That rate of current continues from this point to the dam. The rate per mile per hour above Kampsville is about the same until you get above the back-water of this dam and it gradually increases as you go up.

3061 There is not very much green scum or moss in the river now. German carp seem to prosper best in the river at this place. German carp feed on all the scavenger stuff they can get; horse manure or any kind of manure or anything of that kind; filth and animal matter. I do not know that they feed on fish or minnows. This ain't such a big community but what you can tell when a case of sickness comes up. I only know what I hear and come in contact with. My opinion on the water is based from what I know and what everybody teaches me, that the swifter the current the better and purer the water.

3062 If polluted, that you say is far enough away in rushing over gravel and sand it is bound to purify it more than if it would lay stagnated. I know it from drinking out of streams. I do not know that the water does not contain deleterious substances. I don't know whether it contains more or less since the opening of the canal; I ain't analyzed it any.

JAMES MORAIN, Examined in chief by Judge Johns.

Live at Columbiana, Green county, Illinois. Have been a fisherman for 15 years.

3063 Before opening of canal this river was like a pond here; filthy stuff and a green scum. Smelled some; especially about nine o'clock of a morning when there was no draught that the breeze raises. The moss and slime was bad; plenty of it, all covered; it took two men to get them out sometimes. Since opening of canal we have had a much better current; the water has been much better in my opinion since the opening of the canal; that is, it don't smell. In warm weather we take ice and put it in the river water and use it. The water of the Illinois river when you drink it, does not produce disease. I have lived right here 14 years and I have never had a chill. Neither

3064 I nor any of my family have had typhoid fever. The fishermen who drink the water do not have typhoid fever as I know of. I don't know of anyone here that has had typhoid fever at this place. Have assisted in putting up ice. Since

opening of canal the ice is very nice if we have a head-raise on it; that is it is clear ice. Of course, if we have a head raise you know, there is more muddy water settles in it.

CROSS EXAMINATION, By Mr. Jeffries.

There is a good, strong current from Columbiana and Kampsville to the government dam at Kampsville, one-half a mile below. There is a good, strong current up the river from Columbiana and Kampsville. It gets much stronger as it goes up. It was so dead that the nets would not stand up
3065 before this drainage came in, in low water. The carp thrive best in the Illinois river at this point. They live on such as they can gather; the substance in the water, I reckon, and that they gather floating in it; most anything that they can find floating, bugs and worms and such as that. They don't live on minnows to amount to anything at all. The 3rd year before the opening of the canal, our healthiest fish died. I don't think that there is any healthier fish in the world than the cuigan. That year they died. That was when the river was frozen over with ice. Since the drainage came in it has never killed no fish. Since the opening of the canal they have had a good current from here to Meredosia, which is about forty miles. Before the opening of canal it was like rowing in a pond. We would begin to strike some current then at Graysville I think; that is the first current we would strike between here and Meredosia.
3066 The reason for saying the water is better is because we have a current now. It don't seem to contain substances that are poisonous and injurious to the human system; I use it right smart during this last high water when I used ice in it; I have got a family of six of us, and my doctor bill is very little.

3067 IRA DAVIDSON, Examined in chief by Mr. Todd.

Kampsville is my postoffice. Am a fisherman and have been for year and a half. Came here from St. Louis. Lived in St. Louis two years and prior to that time lived in Green county,

Illinois. I lived 8 or 10 miles from the river but I crossed the river twice a week every week for about 3 or 4 years. Before 1900 the Illinois river was low and no current practically.

3068 The water was dark and had green scum on it. Since opening of canal water has been clearer and we haven't had any scum or grass. There has been no odor. Have been on the river 18 months out of the last two years. Drank the water as often as half a dozen times a day. Never taken a dose of medicine since I have been here. About 40 fishermen are engaged in fishing at this point. They are in the habit of drinking the water of the Illinois river when out fishing.

3069 There has been no typhoid fever or sickness in this community during the last 18 months, that I know of. Opening of drainage canal has made the water better.

CROSS EXAMINATION, By Mr. Jeffries.

Use water from a well where we live.

3070 There is a good current in the river now, at Kampsville. That current continues from here to the government dam about one-half a mile below. The farther from the dam you get the stronger the current. The depth of the water flowing over this dam is 3 or more feet. The water never injured my health.

3071 Carp thrive best in the Illinois river. I have never seen anything they wouldn't eat. Cat, buffalo, bass and perch also thrive here besides the carp.

W. L. FLATT, Examined in chief by Mr. Todd.

Live in Columbiana. I fish and have been a fisherman for about 10 years. Been acquainted with the Illinois river for 40 years. Before opening of canal there was more or

3072 less of a scum on the river; in low water and hot weather. It had a smell to it. There was dead fish in the water at that time. Since opening of canal water is more clear; hasn't been so muddy. There has been no green scum on the water. It has a clear color more or less only when it rains. It has im-

proved the water I think. I have drank the water. It has never made me sick since the canal has been put through.

3073 CROSS EXAMINATION, By Mr. Jeffries.

I had the ague before the opening of the canal; I don't know whether the water did it or not. Am 53 years old. Have a well at my residence. I don't know whether the water contains deleterious matter or not.

ISAAC STABLER, Examined in chief by Mr. Todd.

I live in Columbiana, Green county, across the river from Kampsville. Have lived here since 8th of last October. Before that lived in Montezuma on the banks of the Illi-

3074 nois river, for 7 years. Am fisherman and been engaged in that business about 28 years. Prior to opening of canal as near as I can recollect, the water was pretty badly stagnated; about that time there was a heavy green scum on the water and since that time I haven't noticed it; since this drainage has been turned in I haven't noticed that scum. Before opening of canal color of water was dingy green. Water had bad smell and didn't have a good color. Opening of the canal has given river a good current and I think it carried off the filth and it don't have the green scum that raises on the water. I think it made the water more pure than it was before.

If we have a freshet it doesn't take it near as long to

3075 clear up as it did before. The color is much better than before and no odor whatever. Drink the water occasionally. It tastes a great deal better than it did before; it is more clear and pure. The drinking of the water has had no deleterious effect whatever upon me. The fishermen generally drink the water. Assist every year with taking ice from river. I think our ice is more pure. It is more clear; we don't get no moss in the ice since that and we always did before; it was impossible to get it without moss, or a green substance of some kind. Before canal was turned in our nets would all

3076 turn green and form a scum all through the meshes so you couldn't hardly hold the nets. We can place the nets most anywhere we choose now and the scum don't pull

them any more. Opening of canal gives river more current, it gives it more power which leads off and carries away faster; I did think at one time that it was a discharge, but I don't now, but that was only the rising of the water in the Spring, but I see the current now carries the water away a great deal faster than it did before it was turned in. I think it purified the water simply because we have got a better body of water than we had before and a stronger current, and the water can't help but be better than it was before because we have more of it.

3077 CROSS EXAMINATION by Mr. Jeffries.

Am acquainted with the river up as far as Peoria, which is maybe 110 miles and I am acquainted down the river to its mouth. Since opening of the canal the current from Peoria to Grafton is more stronger; it has a stronger current and carries water away faster. The water before opening of the canal was still. We have a right smart current now; more than we

3078 had before. There is a very strong current now; there is a strong current here in the Illinois river which is one-half mile above the Kampsville dam. The stage of the water is about the same or little higher than the month the canal was opened. There will always be a good current here at Kampsville. As you go up the river from Kampsville the cur-

3079 rent gets stronger. I live in a cabin boat on the bank of the river. Carp thrive best in the water here. They feed on anything most; anything in the shape of something to eat. They feed on minnows. Not as well as they do on other matters. They feed principally on grass and moss and go in the mud after mussels. I don't think the water contains deleri-ous substances. I have been around it a good deal and I never found anything like that. Never examined it chemically.

JOHN M. HIPPLE, examined in chief by Mr. Johns.

3080 Live in Kampsville for the last three years. Am pilot on the river in the employ of the government. Am pilot in season and in winter, day watchman on the fleet of three dredges, three steamboats and quarter boats and scows. Have

been in employ of government three years last May. Prior to that I lived on the river all my life and ferried and fished and steam-boated. I am 38 years old and have been on the river 30 years. Most of the dredging operations has been below here. In dredging below here we find mostly sand and mussel shells and in some places we strike mud; some places thin and other places stiffer, and gumbo, but the most of it was sand and mussel shells.

3081 Worked one season with the dredges prior to opening of canal between the locks here and the Six Mile Island which is at the mouth of the river. I couldn't say whether there was much difference in the material dredged before the opening of the canal. I saw the material but the mud was different in so many places. Prior to opening of the canal there was sediment in places, but not in the channel, but out at one side and behind the island, and where there was slack water, and the river had filled in, there was, but it hadn't filled in the channel; around the creeks and where the creeks empty it fills in some and changes. Before opening of the canal the water of the river at low water got very filthy and green. Filth was caused by lack of current to drive it away. Filth was from both decayed vegetation and from sewage but mostly from sewage. From Peoria to LaSalle in low water it was filthy and dirty. It seemed to be more filthy about the Henry lock.

3082 When we got over the Henry dam it got better, when we got down to Peoria or down near to Peoria. The stretch from Peoria to Copperas Creek dam was very bad, very bad. It was a good deal worse down below Peoria than it was above. I think it was on account of sewage from Peoria—no current to drive it away. Since the opening of the canal the water below Peoria and the Copperas Creek dam is much improved. I was over it yesterday and it looks as well as the river down here. It is 30 miles from Peoria to Copperas Creek and from Copperas Creek to La Grange dam it is 82 miles according to steamboat men. From La Grange dam to Kampsville dam is 60 miles.

3083 Prior to opening of drainage canal the water between Copperas Creek and La Grange was a good deal better than it was above; after it went over the dam it didn't get bad again until it got down to Beardstown, or near the other lock—down to La Grange lock. Since the opening of the canal that stretch of water seems to be a great deal improved. Before opening of canal the stretch of water between La Grange and Kampsville wasn't near as bad as it was up above Copperas Creek, but it is better now than it was then. The river is in better condition now than it was then.

Prior to the opening of the Drainage canal the water of the Illinois river improves as it travels from LaSalle to Peoria Lake. Since the opening of the canal the water from LaSalle to Peoria Lake improves as it travels. Prior to opening

3084 of canal the water immediately below Peoria was in worse condition than at LaSalle. The water below Peoria was the worst; the water above Peoria was the best.

Q. Did the water as it traveled from Peoria to Copperas Creek dam improve in appearance?

A. No, it seemed like it got worse until after it came over the dam and then it seemed to improve. It had to come to Pekin you know and there it got mixed with a lot more. Between Peoria and Copperas Creek dam there was a large amount of sewage and offal added to the water in the river at Pekin. Before the opening of the canal the water in the Illinois river appeared to improve between La Grange and Kampsville; and between Kampsville and Grafton. Since the opening of the drainage canal the waters of the Illinois river appear to improve between LaSalle and Peoria. The waters in that stretch of the Illinois river are better since the opening of the drainage canal than before.

3085 Since the opening of the drainage canal the waters of the Illinois river between Copperas Creek dam and Peoria are better as compared with their condition before the opening of the Drainage canal. The water looks better. Since the opening of the Drainage canal the waters of the Illinois river be-

tween Copperas Creek dam and La Grange dam are better and purer and not so much vegetation and green stuff. The further down this way the better the water is. Between La Grange and Kampsville the waters of the river are better since the opening of the canal. Since the opening of the canal the waters below Kampsville dam to Grafton are improved some; the waters are better, but you can't notice it here like you can on the upper end.

Q. Since the opening of the drainage canal, you may state whether the waters of the Illinois river gradually and steadily improved from LaSalle to Peoria Lake.

Objected to as leading, and misleading.

A. Navigation improved, yes sir; wonderfully. It looks clearer. From LaSalle to Peoria the water looks clearer.

Q. Since the opening of the canal do the waters of the Illinois river improve between Peoria and Copperas Creek dam, and if not, state why?

Objected to as leading and suggestive.

3086 A. Yes, sir; they improve.

The amount of offal and sewage these waters receive at Pekin is considerable.

Since the opening of the canal the waters of the Illinois river improve in condition between Copperas Creek and La Grange; between La Grange and Kampsville and between Kampsville and Grafton. Couldn't see any difference in the ice as a general rule taken before opening of canal or afterwards as to whether it was clearer or not. Have been drinking waters of the Illinois since I was 8 years old. Fishermen on river drink the water as a rule. Men in the employ of the government on the dredging fleets drink the waters of the Illinois. If any of them ever had typhoid I never heard of it. The use of

3087 the dams in the Illinois river is to back up the water over the bars. These dams retard or stop the flow of the river up to their aprons. Kampsville dam backs up the water as far up as LaGrange, 50 miles. LaGrange dam backs the water up 50 or 60 miles. Copperas Creek dam backs up the water 40 or 50 miles. Henry dam backs up the water for about 40 miles.

High water in the Illinois river causes the channel to fill up. The flood in the Illinois river does not wash out the channel and remove whatever sediment there is in it.

3088 High water in the tributaries of the Illinois is the cause of deposits filling and bars forming in the Illinois. Dredging is done to deepen the channel so steamboats can run. Dredging is done where bars are formed. These bars form in the Illinois river generally below the entrance of the tributaries. In my experience in dredging on the Illinois river I find that the channel below the entrance of tributaries quite often fills up after high water or flood below the entrance of tributaries. It don't fill up every time a creek comes out.

3089 In times of flood the Illinois river does not always wash out all the sediments deposited between its banks and carry it away. The deposits in the river outside of the running channel was increased by this year's flood, but as a general thing it is diminished. That depends somewhat upon the character of the flood.

3090 CROSS EXAMINATION, By Mr. Jeffries.

3091 Commenced service for the government in May, 1899.

3092 Government had been dredging in Illinois river prior to that time. In some places they went over it and had to re-dig it out; it might have been a deposit; most of the places where the dredging was done it was a natural bed, but in some places it was a deposit.

3093 All these places pretty near all fill up and they have to re-dig them. (Witness states various places where dredging was done.) We are dragging the mud out of the locks here at Kampsville. The mud that comes out of those locks is very thin and awful dark. The mud we are digging now varies in depth—some places 5 or 6 feet deep. At LaGrange dam the mud was 4 or 5 feet or more. We take out the mud out

3095 of the channel and dump it—just move it out of the channel. Along here at Kampsville there was no current in the river prior to the opening of the canal. The water

was all green out here; just plumb green like a pond. Since the canal was opened there has been a fair current when the water was low; it was not a good current, exactly. I don't know that the water is better from a scientific standpoint; I know it's better navigating and it is better to drink and it looks better.

3096 C. V. BRAINARD, Examined in chief by Mr. Todd.

Am a civil engineer. Had charge of the taking of water above Kampsville lock for the sanitary district of Chicago and University of Illinois and University of Chicago. Water was taken in parts of 1900 and 1899. (States method pursued in taking samples, marking them, etc.)

3098 Card used for sample No. 1242 offered as "Sanitary District Exhibit 6 for identification."

Been connected with the government improvement on the Illinois river since February, 1891. At low water the waters of the Illinois river got very bad before opening of canal. There would always be a greasy sort of a scum on the top of it; it would frequently be green the whole depth of the river. There was always more or less of an odor to it. It hasn't been as bad since the opening of the canal. There has been more current and there hasn't been that bad look to it; it has always looked clearer and better than it did before. The color has been better. Before the drainage water was turned in we frequently had grass growing in the river up to the side of the channel where the steamboats kept it worn away; since the water of the drainage canal has been turned in I have seen none of that.

3099 I don't think the water of the canal has injured the waters of the Illinois at all; there has been improvement for the time it has been in, over what it was for certain years before. There was one case of typhoid in Kampsville since the opening of canal. That was the doctor. He had been attending typhoid patients back from the river and we suppose he got it from that. There are ten or a dozen fishermen in this vicin-

ity engaged in fishing. The number of people living along the Illinois river in flat boats is very large; probably several thousand. They live with their wives and children and form a floating population.

3100 CROSS EXAMINATION, By Mr. Jeffries.

The water in the current has increased both above and below the dam. Sometimes we use water from the town wells and we use it from the river at times. When I say the water is better now than before I simply judge from its appearance. I know nothing about its sanitary or unsanitary condition because have made no analysis of it.

3101 RE-CROSS EXAMINATION, By Mr. Todd.

We have used the water where we live at the lock for domestic purposes ever since we have been there. I don't know whether the water caused it or not, we have all had chills and fever. My family consists of myself, my wife and three children.

FRANK TOZIER, Examined in chief by Judge Johns.

Residence is at Kampsville. Am a steamboat engineer. Have been such for 15 or 20 years all told. All the steamboating I ever did was on the Illinois river. Am now in employ of government as engineer; blacksmith.

3102 The only dredging being done now is at the mouth of the locks. We have done no dredging last year nor the forepart of this year. I dredged over 8 years as a steady work. dredged from the upper end of the river from Devil's Elbow, which is eight miles this side of Havana, and every bar to the mouth of the river. The purpose of dredging is to make a channel. When we dredge we get clay, sand, clam shells and soft mud. Dredged many places more than once. The creeks cause the channels we have dredged to fill up. When the creeks are in flood they carry out dirt which fills up the channels. The bars in the river are below the creeks.

3103 I think very nearly the whole cause of the formation of bars in the Illinois river is the sediment that comes out of the creeks. After each high water there will be a sediment

of an inch or two inches; sometimes maybe three all over the banks, on the flats will be an inch to three and four inches of a sediment, after a long high water. This year there was about 3 inches. When there is high water in the Illinois river I think it causes more sediment to settle; there isn't current enough in this river to wash out anything.

Objected to for the reason has not qualified.

I have dredged out a place upon the Illinois river where afterwards I was not able to find the channel again. That was at Otter Creek bar; we dredged it out and then moved up on the other bar and then in two or three weeks we had to go and dredge it again. A storm came up right after we had dredged it and when we went back after two or three weeks we couldn't find where we had dredged. It filled up on account of a flood in Otter creek. The bars form again after being dredged because there has been a flood in the creeks; I have dredged
3104 bars where it was quicksand and came right back. We drink the water of the Illinois when we are out dredging. We use the water with ice. Don't use ice water when water is cool. The water does not give us any disease. The government fleet now on the Illinois river consists of 3 barges, 3 steamers, 8 dump scows, 4 flats, 2 quarter boats and an officer's boat. 40 or 50 men are employed on this fleet. These men generally drink the water of the Illinois river. It doesn't seem to have any bad effect upon them. Most of them are in good
3105 health the whole thing through. Once in a while there will be one that will have a chill. Prior to opening of canal you could find this whole river here as far as you could see covered with a green slime all over it. We don't have that and haven't had it for the last two years. May be one of the hot days you may see a little streak of that green right where the channel comes, but very little of it. The water now with ice in it, I believe would be perfectly healthy right at the present time. I believe it will be fit to drink the year around. After

the weather begins to get cold in the fall we drink it right out of the river.

3106 The purpose of putting dams in the Illinois river is to raise the river so boats could run. The dam at Kampsvills backs up the water so that it will make at Meredosia about six inches of water. A raise of seven feet here will make it about six inches at Meredosia. It is about 42 miles from Kampsville to Meredosia. LaGrange dam is about 7 miles from Meredosia. The LaGrange dam was calculated to back the water clear to Copperas creek lock, but it don't do it. It is 7 feet high. The Copperas creek dam backs the water up between Henry and Lacob. It is about 70 miles from Copperas creek dam to Henry dam. The Henry dam used to back the water plumb to La Salle.

3107 It is about 40 miles from Henry dam to LaSalle. The dams on the Illinois river are 7 feet high from dead low water.

CROSS EXAMINATION, By Mr. Jeffries.

The last piece of dredging was done about three years ago. What we are doing now we do not call dredging—it is cleaning up around locks and the like of that.

3108 There has been no dredging since 1900. Prior to 1900 we dredged for 7 years right straight. Am a married man and live at Kampsville. Have a well at home, but don't use that for drinking and domestic purposes at the present time. I would rather take it out of the river than out of the well.

3109 Am using out of a neighbor's well now, though. This is the only dredging outfit on this river now. There is another outfit that belongs to the State.

3110 VALENTINE TOTZELL, Examined in chief by Mr. Todd.

Am a fisherman. Have been a fisherman since 1874 on the Illinois river. Live at Kampsville. Prior to the opening of the canal the river was stagnated water—green. I have seen it here one season when the water was green fully six inches

deep. If you dipped up a bucket of water it would be perfectly green. There were times that there was a kind of a bad smell, coming in kind of puffs like. Since the opening of the canal we have had better water, that is, say six or eight weeks after the canal was let in, we had pretty bad water, the water was colored. At the same time it was cold weather; it was kind of a coffee-colored brown, but then six or seven weeks after that it cleared out and we have had good water since. We have got a better current now than we generally have.

3111 There is no smell that I could catch. I drink the water now regularly. Before the ditch was in, we couldn't drink it at all. Drinking the water has had no effect on my health that I can see. I have always been hardy since I have been on the river. If turning in the drainage canal had any effect at all, it would give us better water—I mean purer water and more of it. Before the opening of the canal there was several times when the river was very low that we had no current at all and it was dead water above the locks here. Three times I have raised, all the fish in my nets were dead. There was a kind of slime formed on the nets.

3112 Since the opening of the canal the fish keep better in live boxes and you can leave them longer in nets without raising them and they won't bruise themselves or die with disease as they would before.

CROSS EXAMINATION, By Mr. Jeffries.

Use water from a well for domestic purposes. I can drink the water now when I couldn't before, the year around. I could drink it before but there were times in the year when I couldn't. The most fish that we have is German carp at the present day. They feed on everything that I have tried yet—potatoes, meal, flour or anything else. They feed on animal matter.

3113 We have a fair current now which we did no thave before the ditch came in. The people here in town have wells and cisterns that they use water out of.

O. C. BARTHOLOMEW, Examined in chief by Mr. Todd.

Am fisherman. Employ from three to five men in my business, which is a half-mile north of Kampsville. Fish with about 80 nets. Have lived in Kampsville ten years.

3114 Before the opening of the canal here at times, during the summer season, the river would have scum on it and I have seen nothing of that kind since. Before the canal was opened, in the winter after a heavy freeze, there was a smell connected with the water. Since the opening of the canal we have had a right smart current and no scum on the water. We have no scum any more and there seems to be a pretty fair current. The water appears better, it doesn't seem to be as stagnant. I drink the water and have done so since the opening of the canal only through the winter season.

3115 The fishermen also possibly do that when out in the water in the winter season.

CROSS EXAMINATION, By Mr. Jeffries.

All the people around here have wells or cisterns and use the water from those wells for domestic purposes. I do not know whether the water contains deleterious matters or not. Before the opening of the canal, there was no current, the stuff went which ever way the wind was. Now, we have a fair current all the time, both in high and low water. There is a current here opposite this place.

3116 The farther up you get the stiffer current you get until you reach the other lock. Two years ago the Illinois river was lower than it is today—that was in 1901 during the drought.

WILLIAM MAPPIN, Examined in chief by Mr. Todd.

Am fisherman. Live at Kampsville. Have lived here 7 years. The water in the river was pretty bad before opening of the canal. At times would get down pretty low and there was a right smart scum on it. It had an odor. I drank it then once in a while when we were seining. The water now is purer and better. There is not the sediment. We don't have any scum. Of course, it doesn't get down now like it did then. I suppose that is the reason. I don't drink the water now. I think the

water is better. I don't see why it wouldn't be. We have got a good current in the river. We have what we call low water for a couple of months.

3118 We have high water for the rest of the year.

CROSS EXAMINATION, By Mr. Jeffries.

By high water I mean that the water is above low water mark. In July and August as a general thing the water gets down about the lowest. When I say the water is better I mean simply from my observation and my belief is based altogether upon the fact that there is no more stagnant water and that we have a continuous current through the year. I live on a boat right up on the bank of the river. Prior to the opening of the canal there was little or no current here at all. Whichever way the wind blew that was the way the current went.

3119 It is a pretty good current now. There is no stagnant water. The current gets stronger as you go up above.

DR. T. O. HARDESTY, Examined in chief by Judge Johns.

Have been practicing medicine since 1896, in Kamps-

3120 ville. I cover a territory ten miles on the north, 9 miles on the south and 8 miles on the west. A very small proportion of the population in this territory use Illinois river water for domestic purposes. In my opinion the fishermen use it when engaged in their business. I have had no typical cases of typhoid fever. We have every summer a number of cases. We call them typho-malaria. These cases no doubt are a modified form of typhoid fever. The cases that I have had to do with have been practically altogether situated in the hills, back three or four miles from the river.

3121 My observation has been that within the last three years there has been less sickness in this community than there has been in the time that I have been practicing here.

CROSS EXAMINATION, By Mr. Jeffries.

The census gives this town a population of 320. As far as my information goes, the people here use well and cistern water for domestic purposes. The farmers use mostly spring or living wells.

3122 EDWARD DAUGHERTY, Examined in chief by Judge Johns.

Am a carpenter. Live at Kampsville. Have been on or near the Illinois river 30 years. Have been employed by the government on the Illinois river since the spring of 1882 as carpenter and cranesman on the dredges. Have been connected with the business of dredging the Illinois river for 21 years.

3123 Have been dredging from Devil's Elbow, 4 miles below Havana to Six-Mile Island, about six miles above Grafton. The dredging operations are carried on in the Illinois river in the fall. The object is to deepen the channels and dredge out bars which have formed in the river, as a general rule below creeks. These bars are formed by creeks overflowing and throwing out their sediment into the river.

3124 We have dredged several places three or four times. These dredgings generally have been below the mouths of tributaries of the Illinois river. I have not noticed any serious results from the sediment during the times of floods in the Illinois river. The river does not scour in times of flood or high water. There is more sediment every time there is a flood.

3125 In the course of my business in dredging I always drank the Illinois river water in its unfiltered state. Forty-five men are in the employ of the government on the river while dredging operations are conducted. They drink Illinois river water. I do not know of one case of typhoid fever among our dredgmen. I had typhoid fever once in Cass county, 7½ miles east of the Illinois river. I was only about 15 years old when I had it.

3126 I know it left me bald-headed. The skin came off my body, hands and feet. I was not able to be up for about three months after I was taken. I did not fairly get over it for fifteen years. Have not seen among the men engaged in the employ of the government any such disease as that. Prior to

the opening of the canal the color of the water from Devil's Elbow to Six-Mile Island was green—stagnated. Stirring the water with an oar you would find it to be ropey, with a green fiber in it for about two feet down and very little current, unless we had a big head raise a little up the river. The odor here one winter when it froze up was terribly bad, after it got broken up in the spring and the ice got broken so it could get out. That was the only time I noticed any bad odor.

3127 Since the opening of the canal the river has been a good deal healthier. We have had a better current and it is bound to be better drinking water. It seems to be more pure. The character of the material dredged varies. In dredging out a second or third time, it is a soft, mushy mud, as nearly as I can tell you. The first dredgings are mussel shells and mud and dirt and a lot of sand. There aint any clay in the Illinois river except at two places that I have dredged. The clay is blue at LaGrange and down here below, it is yellow. I don't believe I ever noticed any gumbo in the bottom of the Illinois river.

CROSS EXAMINATION, By Mr. Jeffries.

3128 The last dredging we did was in 1900, all the way along up.

3129 After those shallow places had been dredged out the matter that was deposited there was mostly mud. That was generally true of all the places as to the second dredging and the third. It would be thin, sloppy mud. In places right close to those creeks it would be almost level; that is the cut would be filled level with the original bottom of the river.

Q. What do you mean by being filled level with the original bottom of the river?

A. When we would dig down, say three feet through this bar, then the creek would come down and fill that three-foot cut up again with the original bottom of the river; that would be the original bottom again, that cut. When I say the water is

better, I take my judgement from the look of the water and the current and condition of the water before and now.

3130 Before the ojening of the canal there was no current. Since the opening we have always had a good current. Opposite Kampsville we have got about a mile or a mile and a half an hour. The current continues from here to the dam and on over the dam. I don't think it changes much as you go up. It is about as swift at one place as another. When this mud and filth is taken up out of the bottom of the river in these places where we have dredged, it is generally taken out and put in behind islands, when it is possible to get behind an island. If not, then right up on the bank as near as we can get it.

3131 There would be a little current 15 feet from the bank, certainly. The people in town use well water for domestic and drinking purposes. Am a man of family. I use well water.

DR. T. O. HARDESTY, Recalled. Examined by Judge Johns.

I was taken sick September 26, 1902, and confined to my bed for eight weeks. The diagnosis was typhoid fever. Prior to getting sick I had treated two cases in August—the latter part of July and August for what we diagnose in this country as typho-malarial fever. The weather was very warm and my opinion was that in drinking the water that I would find at these houses when I would go there, that I contracted the disease from these two patients. Those two cases were five miles south of Kampsville and two and a half miles west of the river.

3132 The people who had the cases did not use Illinois river water for drinking purposes. The urinary and fecal discharges from my own person at that time were just thrown outside on the ground, and not disinfected.

RE-CROSS EXAMINATION, By Mr. Jeffries.

One of the patients was a male and the other was a female. The gentleman had opportunities to drink water away from

home. He was running a threshing machine. The lady did not. The sickness of one ran into the other, one was sick and the other was taken sick a couple of weeks later. The gentleman was a man of family. The lady was a young girl about sixteen. The man had done some threshing along the bluffs. My opinion was that I contracted the disease from one or the other of those two patients. I was just as likely to have taken a drink at some other place as at these two houses, but these two cases were the only cases I had last summer of typhoid fever.

3133 DR. FREDERICK W. RUNDE, Examined in chief by Judge Johns.

Have been practicing medicine since 1898.

3134 Practiced in Denver, Colo. a year and a half and the balance of the time at this place. Have been in Kampsville four years on the 26th of November. I have had two cases of typhoid fever in this vicinity. One was that of Dr. Hardesty, the other was three miles south of Kampsville, a mile and a quarter from the Illinois river. The person having the fever did not drink the waters of the Illinois river, to my knowledge. The condition of the health of the people of this community since the opening of the canal has been fairly good.

3135 As far as my knowledge is concerned, very few people drink the river water except those who probably live along the river and can't get anything else. There is just as much malarial disease out in the hills as along the river. I also conduct a pharmacy. Since the opening of the canal the sales of patent medicines are a great deal less and especially anti-malarial medicines.

CROSS EXAMINATION, By Mr. Jeffries.

Am a married man. Use well water at home. Use well water in the preparation of my prescriptions.

3136 ALBERT R. ZIMMERMAN, Examined in chief by Judge Johns.

Live at Kampsville. Am a ship carpenter and calker by trade. Am 44 years old and have been on this river 43 years.

Am familiar with the river from 12-Mile Island to Havana. Before 1900 during low water the river was very low and there was a great deal of green stuff and such as that floating on the river. The water would get pretty green, all over the top of the river. Pulling a skiff over the river you could see the mark of the boat right through the green stuff. I noticed a

3137 few years ago that the odor was so bad you could scarcely stand it at all up there at LaGrange locks. We used to use it for washing purposes and for drinking purposes, but it got so bad we couldn't even stand the smell of the water in the house, boiling on the stove. We had to quit using it entirely for washing purposes. We used to drink it very nearly altogether when we were out with the fleet dredging. I have never heard of a genuine case of typhoid fever right on the river bank in my life, since I have been on it. All the typhoid fever that ever I heard of I know has been back of the river. Since the opening of the canal we have had a higher stage of water, more current, and as far as speaking about the condition of the water in general, whether it has been a benefit or detriment to the water, I could not say. I don't see so much of that green stuff in the river. We have drank the water since, and as far as drinking it, we can't tell any difference in the taste of it and we don't find any more sediment in the water than we did before. I presume, taking the water in general, of the Illinois river, it is today, I believe, really better than before the canal went in.

3138 CROSS EXAMINATION, By Mr. Jeffries.

I never analyzed the water. I can't tell whether it contains deleterious matter or not. Am a man of family. Use well water at home for drinking and domestic purposes. Before the opening of the canal there was not very much of a current in the river.

3139 There is a fairly good current in the river for the last two or three years.

C. V. BRAINARD, Examined in chief by Judge Johns.

In my employment by the government I have been in charge of all the dredging operations that have been done in the Illinois river in the last 12 years and a half, from Copperas Creek lock to the mouth. I accompanied the dredge boats at times. The material that is dredged from the Illinois river is some sand, some clay and some mud. Most of the dredging has been done between Kampsville and the mouth of the river, also between Kampsville and Copperas Creek locks. The purpose of the dredging is to deepen the channel and is done largely where bars have formed, in order to cut a channel through them. The

majority of the dredging that has been done is to cut
3140 these bars that have been formed for years and have been

an obstruction to navigation for probably 20 years and they exist in all points of the river, but the new bars forming are generally below the mouths of the creeks. After high waters, we frequently find some of our channels filled up. That is usually in parts of the river that are affected by back water from the Mississippi. This may be caused by two reasons, either that the water that is entering the river from the Mississippi is full of sediment which is deposited when the current is slack, or it may be that the water coming from above in the Illinois river, deposits the sediment into the slack water that is formed from above in the Illinois river, by emptying into the back water of the Mississippi; the deposits may be made in

either of the two ways.

3141 Before the opening of the drainage canal in 1900 I never

knew of the Illinois river scouring and cleaning itself in times of high water. Since the opening of the canal it does not scour and clean itself any more than it did before. Before and since the opening of the canal if sedimentary matter is deposited in the Illinois river, the only way it is removed is by dredging it, or some mechanical process. The river does not clean itself at all that I have ever been able to find out. During the high water of the past spring I was told by Mr. Worman of

the government survey, that he had obtained data that indicated that the current flowed up-stream above what is known as the Griggsville Bridge, about 60 miles from the mouth of the river. (Motion to strike out, by Mr. Jeffries, as hearsay.) The excessive rise in the Mississippi river occasioned this reversal of the current of the Illinois river.

CROSS EXAMINATION, By Mr. Jeffries.

(Motion to strike out all the evidence of this witness taken today.)

3142 Coperas Creek dam is 106 miles from Kampsville. Records are kept of all this work and in those records are daily statements of the amount of deposits removed, the character of the deposit and the disposition made of it. I have a copy of that record here in my office and there is a copy in Chicago, in the office of the district engineer. Those records cannot be removed from my office, but a copy of them could probably be obtained. Where we have been dredging in these various places the mud might be from a few inches to three or four feet. We finished dredging below the mouth of what is known as Otter Creek below here, one night and moved up half or three-quarters of a mile and began dredging again, and there was a big storm up Otter Creek that night and the next morning we found that there had been a deposit of over a foot in our dredged channel from that storm. Another instance was at French Bar; we dredged from that for about a mile in 1894, and in 1899 we went back to widen the channel; we found that during the high water of 1899 that in parts of that old channel there had been from three to four feet of a deposit, and this was caused by backwater from the Mississippi. It has been two years this summer since there has been any dredging done on the river.

JAMES R. FULLER, Examined in chief by Judge Johns.

Live at Kampsville. Am in government's employ as overseer of Illinois river crew.

3144 Have been in employ of the government 13 years altogether as clerk and overseer. I have charge of repairs

and construction work and dredging operations under the supervision of the assistant engineer, when he is there. When he isn't there I have the same duties that he has. W. M. Charles was assistant engineer when I first came on board and C. V. Brainard since. As far as I am concerned myself I have not done any dredging above Meredosia, between Meredosia and Six-Mile Island. The dredging is done to improve navigation. The dredging is done through bars that have principally been in the river and always were in the river, through bars only. As a general rule the channels have been cut 200 feet wide. The dredged material as far as possible is dumped along the shore opposite the dredged channel. The material dredged is sand, mud and mussel shells.

3145 The bars are formed generally below the mouths of the tributaries of the Illinois and are caused by the flood washing it down from these tributaries. The deposits are washed down by the floods. The channels cut in these dams fill up. This is caused by freshets out of these tributaries. We have re-dredged the channels formerly dredged out.

Just now I can only think of two instances, one at French Dam and one at Six-Mile Island—there are four, one at Herriken Island and one at Otter Creek. Floods in the Illinois river will make some deposits along the banks. At the lower end, if we have back water from the Mississippi it is likely to make deposits in the main channel. I have never seen any effects of lifting up and removing sedimentary matter previously deposited, either in the channel or along the banks of the river by floods. If sedimentary deposits are made or occur, dredging as a rule in some form or other is the only means of removing them. The Illinois river before the opening of the canal never scoured or cleaned itself in times of flood that I ever saw.

3146 Since the opening of the canal, the Illinois river does not scour or clean itself in either times of flood or other stages of water. Since the opening of the canal if sedimentary matter occurs, the only means of removing it is by dredging. I should think Copperas Creek dam is seven or eight hundred

feet long. Prior to 1900 the current of the river, especially in low water was sluggish and the river was always muddy. In low water it smelled pretty strong a good deal of the time. I think the water has been clearer since the opening than it ever was before and there is a good deal more current. The men under me that worked in the dredging operations drank the Illinois river water before and after the opening of the drainage canal, part of the time. Occasionally there would be a spring near where we were working and they would drink that water, otherwise they drank the river water.

3147 There has been no typhoid among those men to my knowledge.

CROSS EXAMINATION, By Mr. Jeffries.

I mean to say that in times of high water the river does not cut through these bars and deposits and at places form new channels. The river don't cut out channels, don't change a channel from itself. It won't cut a channel through these bars. In my experience the channel never changes from the river itself. I never saw this river change a channel from the effects of the water. I have studied civil engineering but not hydraulic engineering.

3148 I never analyzed the water. I don't know anything about it in that respect.

(AT GRAVEL POINT, ILL.)

JOHN WEIMER, Examined in chief by Mr. Todd.

Live at Gravel Point, that is about 40 miles from the mouth of the Illinois and have lived there about three months. Prior to coming here I was employed by the government as dredging engineer in the neighborhood of about 16 years all told on the Mississippi and Illinois rivers. I am acquainted as far up the river as LaSalle and down to the mouth. I have dredged along the river from three miles above Hennepin down to the

3149 mouth. I am familiar with the character of the Mississippi river from Winona to about 20 miles below St. Louis. The Mississippi and Illinois rivers do not compare at all

as to their channels. The Mississippi river moves in its channel and the Illinois stays stationary. The Mississippi river scours and the Illinois river doesn't.

3150 When sedimentary substances are deposited on the bed of the Illinois river I don't see that high water has any effect upon the beds of the stream and the deposits made upon the bed of the stream. High water in the Illinois river will not scour out the bed of the river. I have had experience with the Illinois river that justifies me in making that statement. I have sounded the gauge of the water when we dredged and have sounded it a year or two after we dredged and found about the same water. Freshets in the tributaries of the Illinois have quite an effect on the Illinois river in washing the soil off the hills and carrying it into the river. This soil is deposited at the mouth where it strikes a big body of water where it loses the swiftness of the current. That deposit so made by freshets might subsequently be removed by high water in some cases, but most of the cases it don't on the river.

3151 It might in a case where the river is very close and a creek comes out into the river, while if there is a big stage —a big, flat bed, it won't. It might remove it of its own accord where it is very shallow but in the 12 years I was here we had no such experience, but yet such might be the case. Such bars are removed by dredging. There have been instances where we have dredged out a channel and that channel subsequently filled up. We were down here dredging at 12-Mile Island, right below Macoupin, and we were just about through and we were going to move up the river with the fleet and a rain came that night up the Macoupin and it come down the Macoupin creek an awful strong current, and it regular flooded; it filled up the channel about a foot. I know when the Kampsville and La Grange dams were built.

3152 I don't believe that the river has filled up above those dams by sediment outside of the channel. It might reach above the locks. I don't think that it does but it might be.

When the matter is deposited on the bed of the Illinois river I don't know of any way by which it can be removed except by dredging. High water or current doesn't change the channel in the Illinois river. Current and volume of water in the Mississippi change the channel. That is common on that river. I have found that condition to exist upon the Illinois.

3153 Before the opening of the canal the Illinois river water in low water was stagnated fearful, it was greenish. Since the opening I consider that it has been lots better. I consider it purer now than it was before. It hasn't the odor. Six or seven families are engaged in fishing at this point. I do not know of any typhoid fever among those people. I have drank the water of the river nearly altogether for 12 years both in summer and winter. It is lots better now for drinking purposes than it was before.

CROSS EXAMINATION, By Mr. Jeffries.

3154 Lived at Kampsville before I came here. I have a well here and use the water of the well for domestic and drinking purposes. We quit dredging about 2½ years ago but

3135 we have been continually on the river since. I did my dredging on the Illinois river from Hennepin down to the mouth. Our dredging was sometimes two feet, three feet, or four feet. The material we dredged was very heavy loam and in places in those creeks we would get heavy gravel and mussel shells and necessarily heavy mud in it.

3156 I ain't positive whether the last place I dredged was Hennepin or Kampsville. The material we took out there was principally mud. I made a report of all this dredging and kept a record of the amount of filth and mud that I took from the bottom of the river. The government has it on file. My report is kept at Kampsville.

3157 When I say the water is better I mean I made my observations by using it for drinking purposes. I find it is better now than it was before.

THOMAS J. NELSON, Examined in chief by Mr. Todd.

3158 Am a fisherman. Have been for about six years. In the fall of the year, the Illinois river had a bad current before the opening of the canal. There was a smell to it. It was no current, and green moss and grass grew in it. There hasn't been any since. I don't know whether there was an odor to it. I didn't use any of it. It was impure was all you could call it. The effect of the opening of the canal has been to give it a current and the water has become purer. There is more current in it is all I can say.

CROSS EXAMINATION, By Mr. Jeffries.

3159 I have been farming on the river for the last fifty years. I live in the first house below here. I have a well. I use the water from that for drinking or domestic purposes. I have no information as to whether or not the Illinois river water contains more deleterious matter than it did before. I could not say whether the sewage from Chicago gets down here this far or not.

3160 THOMAS CARTER, Examined in chief by Mr. Todd.

Live at Gravel Point. Have been a fisherman for 45 years. The Illinois river prior to opening of the canal was stagnated, had a low current, a green scum on it, and a smell in the hot part of the season. The opening of the canal has put some current in it and keeps that green scum off so far that I think the water is purer than it was. Have drank the water since the opening of the canal. I never drank it much in the summer time. There are about five men engaged in the fishing business at this point. I never heard of any typhoid fever among them.

CROSS EXAMINATION, By Mr. Jeffries.

Have been living here about 25 or 30 years and fishing all the time. I live in a house and have a well and use water out of that for household and domestic purposes. When I say the water is better now than it was before, I mean it has a better current and a larger volume of water. I couldn't say whether

the water contains more deleterious matter than it did before. It isn't used very much for drinking purposes, only when you get out on the river and want a drink and haven't got anything else.

3162 RE-DIRECT EXAMINATION, By Mr. Todd.

I don't know as there is any difference in the color of the water. The water before the opening was as clear as it is now, except the scum. I don't know as I said the water was any better. I said there was a better current than there was. I drank the water before and after the opening of the canal. I don't know that I can tell any difference in the taste of it.

3163 GEORGE NELSON, Examined in chief by Mr. Todd.

Am a fisherman. Have been fishing for about seven years. I haven't seen any difference in the condition of the water only in the fall of the year, since the opening of the canal. We have a current now the last three years and the water doesn't get so green and isn't so filthy. I have drank it both before and since the canal was opened. It has a better color and is purer water. I don't see any green scum upon it now.

3164 CROSS EXAMINATION, By Mr. Jeffries.

We use well water at home for drinking and household use. When I am around home I always drink out of the well but lots of times I am caught out when I have to drink river water. There is a good deal of difference in the water; before this water came in, it was a regular lake, the water was green, now there is a reasonable fair current here. That is the main difference. I don't know whether Chicago sewage gets down this far or not.

3165 RE-DIRECT EXAMINATION, By Mr. Todd.

The water is more clearer. It is not so stagnant. More pure. Of course the current was pure water since the opening of the canal and before that it was stagnant.

S. D. THURSTON, Examined in chief by Mr. Todd.

Am a fisherman and have been such for three years steady. Before that time I farmed. I have lived along the river most of my life.

3166 Before the canal was opened the river was stagnant in low water; there was a green scum on it and an odor in hot weather. Since the opening there is a better current and a clearer water in the winter season anyway. I would say better, in fact. There is no scum on it now this low down. I saw it over at Peoria. I drink the water out fishing when it is cold. There has been no sickness among the fishermen in this locality that I know of, nor any cases of typhoid fever.

CROSS EXAMINATION, By Mr. Jeffries.

3167 I live in a dwelling house and have a well. Use the water from the well for household and drinking purposes. Don't know whether the sewage comes here from Chicago or not. There is more current in the river. Don't drink the water unless I get caught out and have to drink it.

(AT PEARL, ILL.)

MARION HESS, Examined in chief by Judge Johns.

Live in Pearl. I fish and farm some along the river. Have fished off and on for ten or twelve years, 15 miles each way up and down the river. Before the opening of the canal the river was pretty filthy and bad.

3168 During July and August it was pretty filthy, green-looking water. It would form a scum and slime all over the nets. During this time when there was slime and scum upon the waters we drank it, along in the spring of the year. Since January, 1900, the water seems purer and all right. There is a good current. Now whenever I want a drink of water I take the cup and get me a drink most any time. When I can get no other water it does pretty well. I don't know exactly as I know of any typhoid fever among the fishermen since the opening of the canal. I couldn't mention any around here.

3169 CROSS EXAMINATION, By Mr. Jeffries.

Have a well at my home. Use the water from the well for domestic and drinking purposes. When we can't get any other water we use the river water. There was a time in July and August you couldn't drink the water on acocunt of scum

over it. Now we take the bailing cup and dip it down and don't get no scum. It seems to do for thirst. We have a current now all the time. In July and August before the opening of the canal we had no current at all.

3170 E. H. CHANDLER, Examined in chief by Judge Johns.

Am agent of the C. & A. Ry. Co. and U. S. Express Co. Live at Pearl. Took samples of water in 1899 and 1900. Had Joseph Lindsey take the samples personally.

3171 He was about 21 years old and is in the Philippine Islands now as a soldier. (Witness states the times and places at which samples were taken.)

CROSS EXAMINATION, By Mr. Jeffries.

I didn't see Lindsey personally take any of the samples nor see any of the samples taken at any time.

3175 J. RADER, Examined in chief by Judge Johns.

Am a barber and live at Pearl. Know Joseph Lindsey; took samples of water in his stead at various times. He was sick with the measles and I took them while he was sick. (States method of taking samples and places at which they were taken.)

3178 WESLEY FRISE, Examined in chief by Judge Johns.

Live at Pearl. Am a fisherman. Fished on the Illinois river about 12 years, as far up as Hennepin and down to here. Before opening of canal the river water was pretty bad. Stagnated and scum. In summer time when the water got down low it would smell. In the winter time when you cut a hole in the ice there would be regular gas come from the water and I have cut holes in the water where dead fish would come right up through the holes, from gas and stagnated water, I guess. I remember two winters its being that way—one was at Hennepin and the other was at Lacon, but that has been 18 years

3179 ago. Couldn't drink the water prior to January, 1900. Fished at Beardstown and Frederick in 1897, 1898 and 1899. We had some pretty bad water there at that time. While at Beardstown and Frederick, if we cut holes in the ice, the

water would smell and gas would come out. Didn't drink the water at that time, but had to when caught out. Since the opening of the canal I claim the water has been pretty fair, good water.

3180 I never smell anything now. We do drink it now sometimes. I used it a good deal this week when I have been out up the river I drink it right along. It is a good deal better for drinking. I don't see no scum on it now and it is cooler and clearer. I do not know of any cases of typhoid fever among the fishermen since the opening of the canal.

CROSS EXAMINATION, By Mr. Jeffries.

I live on a boat. Have lived on a boat about eight years. There is a good deal more current now than there was before, at all times of the year. I do not know whether the water contains any deleterious substances or not.

3181 Carp thrive best in this river. They feed on pretty nearly everything. With a trout line they will feed on mussells, crawfish and dough-balls. I have catched them on roasting-ears and grains. I don't believe they feed on flesh or dead meat. I never caught any with any. I tried it with beef and never caught any. I believe this current goes up as far as Peoria. I know the water is better. I know it because you don't see the scum along here and this stagnated water and you don't smell this gassy smell any more like you used to. I used to live at Hamburg on the Mississippi. I have seen the Mississippi frozen over several times—for a short time though. I have seen it frozen over at Quincy.

3183 JOHN WINDT, Examined in chief by Judge Johns.

Am a buyer and shipper of fish and live at Pearl. Have been in that business 18 or 19 years. Have been a fisherman myself on the Illinois river. Before the opening of the canal we had a very slow river—no current and no flow and the water would get very stagnant. Had a very bad smell, gas like. In buying and shipping fish used ice in packing them. The ice was from the Illinois river generally. In 1896 and 1897 I put

up ice at Gravel Point, and also at this place and I noticed when cutting ice at that time there was a gassy smell where you would open the ice. The water looked as though there was a dark scum on it. Since the opening of the canal there has been more current and the river clears up faster after a rain or after a flood. I think the water is more clear now. I drank some of it the other night. I never drink it unless I have to.

CROSS EXAMINATION, By Mr. Jeffries.

The people here in Pearl have wells or cisterns. They don't use the Illinois river water without they have to. It is not considered good water by them in the summer season.

3186 There was very little current at times before the canal was opened. There has always been a good current since. It shows that it is better. It is cleaner. We don't have much scum. I don't know whether it contains deleterious matter or not.

JOSEPH HALL, Examined in cheif by Mr. Todd.

Am a fisherman. Have lived at Pearl three years. Before coming here lived at Frederick on the Illinois river four miles above Beardstown. Have been fishing on the river since 1881.

3187 Before the opening of the canal, in the summer time when the water was low, it was pretty bad. Green scum on it. Since the opening of the canal we don't see that any more and the water is more pure. We use the water more or less all the time. The water was better last year than I ever saw it on the Illinois river. I have cut holes in the ice up there at Beardstown, seven years ago this winter and the fish died right in the net and the water smelled so you couldn't hardly stand it. It is better now than I have seen it for a good many years. It is purer, we don't have that gas and no green scum and it has more current. I cut ice every winter. When we cut the ice there is a big difference. The water is pure and clear and you

can see the bottom in five or six feet of water and the water tastes better—no gas and no dead fish.

3188 I drink the water. Have heard of no cases of typhoid fever of people drinking the water. We use the water all the time in the winter time right in the family.

CROSS EXAMINATION, By Mr. Jeffries.

I live in a house boat and have done so about 11 years. There is a larger current now and the water keeps purer. The water is purer. A man can tell it when he drinks it. German carp thrive best in this water. I don't know what they feed on. They bite well on crawfish. There is a good current in the river now and I do not know whether the water contains deleterious matter or not.

3189 I never had it analyzed.

GEORGE HOPPLER, Examined in chief by Mr. Todd.

Live in Pearl and have been a fisherman sixteen years. Before the opening of the canal the Illinois river water in July and August was not very good. It had a green scum on it and in the winter, the water would get so stagnated the fish would die. It smelled awful bad and it would get red. I fished here one winter when we would go and cut our nets out of the hole and there would be fish come up in the hole dead.

3190 There was a substance looked like coal-oil in the water. Since the opening of the canal when the river is froze over it is better. No green scum nor coal-oil substance. The water is a good deal better and purer and there is no odor. I have not drank any water lately but the water looks a great deal better than it did before the canal came in. I have not noticed any deleterious substances in the water.

CROSS EXAMINATION, By Mr. Jeffries.

By the word deleterious I should think it would mean stagnated.

3191 The water isn't stagnated now and it was before the opening of the canal. There is a good current now at

all times. I have lived on a boat about ten years. Always used the water from the river. It gets warm in the summer time and we have to put ice in it. Don't know whether the sewage from Chicago gets down here or not.

3192 (AT NAPLES, ILLINOIS.)

W. H. WATERS, Examined in chief by Judge Johns.

Am a fish dealer and have lived at Naples 24 years. I have also engaged in catching fish by nets as employer and actual worker. I have put up ice in the river on and off for about eight years. Naples is about 38 miles from Kampsville dam, 26 miles from Pearl and 25 miles from Beardstown.

3193 Before the canal was opened we had a very low stage of water at times and in the summer time a little green scum would come on which would last probably for two or three weeks. At that time the fishermen did not drink the water in warm weather, but in the early spring and late fall they did. At that time there wasn't very much sickness here. There was but very few cases of typhoid fever to my knowledge. Since the opening of the canal I don't notice very much difference in this vicinity. I haven't heard of any typhoid here since the opening of the canal. Before the opening of the canal, I noticed no scent particular, but I noticed a green scum.

3194 The condition of the ice varied even before the canal went in. Since the opening of the canal the water has been clearer and purer up to this spring. I haven't analyzed it. There has been no scum on the river. The ice we got was thin and would only freeze about six inches but what we got was good, clear, pure ice.

3195 Before the opening of the canal the people complained about the taste of the fish more than they did the smell. They claimed that they tasted like coal-tar. That was about seven or eight years ago.

CROSS EXAMINATION. By Mr. Jeffries.

Naples has a population of 400. The people have wells mostly—sand pumps. The current has been very sluggish here

this year on account of high water in the Mississippi, the current, as a general thing, since the canal was turned in, is a little swifter. The water from the Mississippi backed up within about seven or eight miles of here last spring. That lasted about two weeks. We didn't have back water here but we had very little current.

3196 Outside of this back water from the Mississippi we have had a good current since the opening of the canal. The water has been all right. We haven't any fish but that thrive well. Carp is more abundant than any other fish. They feed on vegetation in the bottom and some feeds on green grass, green hay, wheat or anything where it would be overflowed. The water is normal now, that is, speaking of it since the opening of the canal. I presume there has been two or three cases of typhoid here in the last several years.

WALLACE HART, Examined in chief by Mr. Todd.

3197 Have lived in Naples 30 years. Am notary public and town clerk. Am 69 years old. Have been familiar with the Illinois river all my life. Have been on and off the river most of the time. Before the opening of the canal the river was low and almost stagnant. There was a green scum on it and a bad smell in the evening. My house is probably half a block from the river and I noticed that smell. Saw lots of dead fish floating in the river. Since the opening of the canal there has been more water in the river and it looks clear and pure to me and I haven't seen any dead fish, scarcely any, since, nor any odor. It is a great deal clearer than it was before.

3198 There are 10 or 12 people engaged in fishing here. Hardly ever hear of a case of typhoid fever for the last two or three years. Naples is about 40 miles from Grafton.

CROSS EXAMINATION, By Mr. Jeffries.

There is much better current now than before the canal was opened. I have a sand pump at home. Get water for household and drinking purposes out of this pump. Those people

that live any ways back from the river don't use the water, but those that live right on the river probably do.

3199 The water doesn't become stagnant like it did and it don't have that smell to it like it did before. I don't know what the water contains in the way of deleterious substances nor whether or not it contains more than it did before the opening of the canal.

WALTER SURRATT, Examined in chief by Mr. Todd.

Am a fisherman and have lived in Naples 20 years.

3200 Before the opening of the canal the river seemed foul and stagnant. Fish wouldn't live in it and water was low and wasn't pure at all. There was a scum on the water during the summer season and at places there was odor where there was a kind of eddy or anything like that. A kind of substance would form on the net and it was something like grease. In fishing under the ice some of the fish would live and part of them would die. The fish did not seem to be healthy and lively as they have been—we would lose some fish. Since the opening of the canal we have got current, none of the green scum and the fish seem to live better. We have more fish in the river to my judgment. It fills up the lakes and I believe it really helps the lakes in purifying, because we don't have near the moss in the lakes we had, as well as the river. The water is more pure than it was.

3201 The ice is clear, before it would be dark. In places you would get moss in the water at low water. In winter we do not have this oily substance in the water that we had before. I haven't discovered any odor under the ice since the opening of the canal. Fish live better in live boxes now. I haven't had any fish die on me this year.

CROSS EXAMINATION, By Mr. Jeffries.

3202 Before the canal was opened, we fished right along. I sold the fish to the markets here. I don't know whether the fish in the Illinois river before the canal was opened, were condemned by the state board of health as unhealthy. I sold my

fish on the market before the canal was opened.

3203 At different periods we have got better current in here and we don't have the stagnated water we had before. We have had a good current for the last two years. I use the town pump. I don't drink the water of the Illinois unless when I am out fishing. I suppose the current has taken that green scum off. I don't know as the water here contains any deleterious matters or not. I have used right smart of the river water and I have been healthy. When I would be out fishing I have drank it. That is the only way I have of judging it. I drank it before the opening.

3204 JAMES WATERS, Examined in chief by Judge Johns.

Have been a fisherman ever since I was big enough to fish. I have fished as far up as Browning, which is 36 miles, and about 10 miles below. Before the canal was opened, the river was kind of stagnated. Slime and scum on the water. It smelled like tar to me. Six or 7 years ago my brother and I were fishing together for some years before the canal was opened; we was raising nets and in the nets would be big catfish and white perch and they would be dead on the ice.

3205 There used to be slime on our nets. It was kind of greenish slime. The nets would not last as long as they do now. Since the opening of the canal the water has been more purified than it was before. There is no smell to it. I know I drank some of it here about a month ago. There is no moss on it that I can see. Before the opening of the canal the fishermen in this community did not drink the water much, to my knowledge. Since the opening of the canal, they do drink it. Among the people who drank the river water before the opening of the canal, there was typhoid fever and a good deal of chills. Since the opening, I don't know of any typhoid fever or chills in town. The ice used to look more slimy and dirty than what it is now.

We put up some as fine ice last winter as we ever have.

3206 CROSS EXAMINATION, By Mr. Jeffries.

That ice was cut out of Smith Lake, a mile and a half or two miles long. It is deeper this year than it generally is.

I live in a house back from the river one block. We have a pump at home.

3207 Used the water from this pump for household and drinking purposes. Never drink the water from the river unless I am out upon it and can't get any other. Before the canal was opened, we sold the fish in the same market that we sell now. There were no objections at that time that they were bad fish that I can remember. I have never seen them die and become as bad as they were those two particular winters, but it was not a continuous thing every winter before the canal was opened. I haven't seen any fish dead in the winter time since the canal was opened. German carp thrive best in this river. I don't know whether they feed on manure. They feed on most anything I guess.

3208 I don't think this water contains anything that would be harmful to the health, because I have used it in the winter time when I was out fishing and I have drank it when I was not working and it has never hurt me. I know of other fishermen being out the same way. There is more current in the river now. There is no time of the year in which there is no current, except from back water.

BENJAMIN FRANKLIN ECKLES, Examined in chief by Judge Johns.

My occupation has been that of farming.

3209 Have lived upon the Illinois river about 15 years. For four years I have lived within eight feet of the bank and that is where I live now. I have lived in this vicinity since 1846. Prior to the opening of the canal when we had a little rain the river was muddy and whenever we had a long dry spell it was clear. There was considerable moss and even grass, but that was years ago. There was a smell to the water in warm weather. Since the opening of the canal I pronounce the water clearer, purer, brighter and better and use it stronger for all uses than I did before. The last four years, I have lived on the river and I have used that river water a good deal for all pur-

poses. In right warm weather I don't use it for drinking but in cool weather I do. In cool weather I use it for drinking, cooking and everything.

3210 The people have splendid pumps here. I haven't suffered from any disease caused by drinking the water, that I know of. I enjoy very good health for a man of my age.

CROSS EXAMINATION, By Mr. Jeffries.

I am 65 years old. Have a better current now than we did before the canal was opened.

3211 (AT MEREDOSIA, ILL.)

JOHN CHRISMAN WORKMAN, Examined in chief by Mr. Todd.

Live in Meredosia. Am a fisherman. Have been working at the business for about 20 years. Prior to the opening of the canal the river was stagnant. Sometimes it was muddy; sometimes it was clear. At times of the year, there was a green scum upon it. At certain times of the year it would smell

3212 bad along the river, the same as it does now. It does that along here now sometimes. It is bound to do that whenever the water gets low, more or less. Two years ago the water here was so low that it dried up in those little lakes up here. Whenever the water gets low and the water gets down off the banks, it is bound to smell. Since that low water that I speak of we haven't had any low water. There is a smell along the river here now, pretty bad too, on account of these mussels.

3213 I don't think I have observed any smell since the canal was opened. The opening of the canal I think, has a tendency to make the water purer. That is, you understand when the water is low; at this time of the year, when the water is high, of course, it don't do it, because it is bound to be muddy when the water is high, but that is because it comes from the rains. As far as the canal is concerned, I think it has a tendency to purify the water at this point. That has always been my argument anyway.

CROSS EXAMINATION, By Mr. Jeffries.

It is a pretty hard question, to tell the difference between the water now and what it was before the canal was opened. It is pretty hard to remember back so far. At a certain time of the year, the water is clear and at other times, it is muddy and that was true before the canal was opened.

3214 I did not say that the water smells now. I say it would whether the water contains deleterious matter or not. We don't whether the water contains deleterious matter or not. I don't drink the water only when necessary.

JULIAN L. GRAHAM, Examined in chief by Mr. Todd.

Am a fisherman. Live at Meredosia. In 1900 the water of the Illinois river was very foul, very low and navigation was almost impossible at times. There was an odor connected with the water.

3215 It has been so low and so foul that it was almost impossible to go bathing. There was a scum on it to such an extent that a person could hardly pull through it at times with a boat. Since the opening of the canal we haven't had any low water. The effect of the opening of the canal has been the best in the world for navigation, sanitary considerations and everything else in that line. There has been no smell since and no scum. I believe it has purified the water itself to a great extent during both winter and summer. Before the opening of the canal there would be a scum on the nets. I don't know as I see much difference now, only it has been an improvement. I don't think I see as much slime and stuff accumulate on the web.

3216 I suppose there would be about 80 or 90 fishermen engaged in the fishing business at this place. Since the opening of the canal, I don't know of any typhoid fever among the fishermen.

CROSS EXAMINATION, By Mr. Jeffries.

Fish about six miles up the river and six down. I think there is a better current in the river now than there was before

the canal was opened. We don't see a particle of green scum. We see the green but we don't see the scum. The scum is decayed vegetable matter but the other is the buds of buck-brush floating down. If there is a current, it passes it through.

3217 Carp thrive best in this water. They feed upon willow flies and of course the parasites in the water and the grasses on the bank, the scum and such stuff as that. They also feed on any kind and all kinds of manure.

RE-DIRECT EXAMINATION, By Mr. Todd.

There are other fish that thrive here. The carp, of course, is the principal fish that thrives. Buffalo thrive, but they can't very well do it. The carp is the only fish that flourishes and the only fish from a financial standpoint for the fishermen. The others don't amount to a continental from a financial standpoint. The carp is the billy-goat of the water.

GEORGE S. LEWIS, Examined in chief by Mr. Todd.

Am a hotel man and live in Meredosia.

3218 Have lived here six years last March. Have spent a good deal of my time on the river. Before the canal was opened the water was low and the current was dead. Next to the bank there was a scum and it seemed kind of stagnant. The opening of the canal has made the water clearer and cooler. I notice it more in my fish that I use here. My fish are better than they were before. I use a good many at the hotel. They are of a good deal better quality than before this water was turned in. I judge the water is purer now than it was before this water was turned in. If it wasn't it wouldn't be so much cooler than it was. I haven't heard of any typhoid fever here since the opening of the canal. I don't pay no attention to things of that kind.

3219 I haven't noticed any smell to the water since the opening of the canal.

CROSS EXAMINATION, By Mr. Jeffries.

We have a drove well at the hotel and use the water from it. We never use the water of the Illinois river here. Our

waters here are all filtered through the sand. Our wells run all the way from 24 to 36 feet. I don't know whether the water contains any deleterious substances or not. The fish that we caught here before the canal was opened were sold on the open market. There is more current in the river now—considerably more.

3220 Prior to the opening of the canal there was a scum on the water on account of the water being low and stagnant. I don't know that the water was clear underneath. I never paid much attention to that. It seems purer now than then.

WILLIAM HAUSER, Examined in chief by Mr. Todd.

Live at Meredosia. Have run this cable ferry 16 or 17 years.

3221 Before the canal was opened, in the fall of the year we had right smart of stagnant water, but since the canal has come in here, our water has been more pure than it was before. In the fall of the year, lots of times, we drink the water when it gets colder and I find that since the canal is in, it is better to drink than it was before. I call it a kind of a grit that makes it taste better than it did before. Before the canal was opened, there was a green scum on it, especially in the fall of the year. That has disapepared. I don't know of any typhoid fever since the opening of the canal. About three years before this canal was opened, I took a scythe and mowed the weeds across the river so I could get through with my ferry boat. Since the canal has been here, I haven't had any trouble with them.

CROSS EXAMINATION, By Mr. Jeffries.

When I spoke of mowing the weeds, it was in the fall of the year when the water would be down. I have seen it here year after year right along. I haven't mowed much in the last five or six years.

3222 We have a whole lot more current now than we had before.

REV. R. G. LINKER, Examined in chief by Mr. Todd.

Am minister of the Gospel. Have preached in Meredosia six years. Before the opening of the canal when the water of the river was low it didn't seem to be as good as now.
3223 I have observed an offensive smell but would not be positive that it came from the river. The effect of the opening of the canal upon the water, in my judgment, is that the water has been better. There has been no typhoid fever among the members of my congregation in the last three years that I know of and no member of the congregation has died from that disease in that time.

CROSS EXAMINATION, By Mr. Jeffries.

We drink the water from what we call drive wells. The people don't use the water of the Illinois river for domestic purposes. When I say the water is better now, I make this statement from my observation and from the appearance of it. I don't know whether the sewage from Chicago affects the water here or not.

A. J. LESLIE, Examined in chief by Mr. Todd.

Am a dealer in grain. Live in Meredosia. Have lived here nearly thirty years, within 100 yards of the river. Before the opening of the canal, in low water, there was a green scum all over the river and sluggish current. There was an odor.
3225 Since the opening of the canal I have never noticed no more of that green scum. The water appears to be clearer and purer and a better current. I haven't noticed any odor particularly for two or three years. I haven't known of any typhoid fever in Meredosia since the opening of the canal.

CROSS EXAMINATION, By Mr. Jeffries.

Before the opening of the canal if the scum was removed, it wasn't so very clear underneath, on account, I suppose, it was more stagnant and not as much current. Naturally the water is not as clear. Am a man of family, have a pump at my home and do not use the water from the river for domestic and drinking purposes.

3226 They cut the ice that they get in the winter time sometimes from Meredosia lake and sometimes from the river —mostly from the river. I don't know anything about the sewage from Chicago coming down here. I don't drink the water from the river and the people around here don't drink it.

F. A. NEVILLE, Examined in chief by Mr. Todd.

Have been a practicing physician for over 16 years. Before the opening of the canal, in the fall the river water would become rather stagnant and green and there would be a good deal of organic material in the water and floating. There was very little current in the water, to speak of.

3227 I believe the opening of the canal has improved the character of the water. The water is more clear and there is less organic material in it. At least I would judge so from the appearance. My practice extends among the fishermen as well as other people. I think there are between 50 and 100 fishermen here. Have had no typhoid fever cases during the last three years from the fishermen, and have not had to exceed one-half dozen cases during that time in Meredosia. None of those cases were attributed to the waters of the Illinois river. In those cases that I had the excreta was disinfected and some of it dumped into sink basins and others dug holes; at least that was what I ordered done. Meredosia has a population of about 800.

CROSS EXAMINATION, By Mr. Jeffries.

I do not use the river water for domestic and drinking purposes.

3228 The people in town do not use it. So far as I know, it was not used for that purpose among any of those patients who were afflicted with typhoid fever that I treated. When I say the water is clearer I say it simply from appearance. I know nothing about the water other than from appearance, and the fact that there is a stronger current and a larger volume of water than there was prior to the opening of the canal.

S. D. ALLEN, Examined in chief by Mr. Todd.

Live in Meredosia and have lived here about 25 years. My business is pumping water out of the Illinois river into a tank for the Wabash Railway Company. I began pumping water in 1896, I think.

3229 Prior to that time I was working here on the bridge about four years. Before the opening of the canal, at low water, the Illinois river was pretty filthy in my estimation. There was green scum on the river and grass growed all up in the water here, and a sediment in the river. The water went down and left all the filth on the ground outside. It was a pretty bad stench here as soon as the water went down and left it. The water acted bad on the boilers before the opening of the canal. It foamed in the boilers. The opening of the canal has been a benefit to the water. The water has been purer. We have used it for drinking purposes on the bridge right along when it was cold enough to use it. There is no odor that I could discern. I haven't seen any of that scum on it. It has been better for steam making purposes. It has not foamed and has not lined the boilers as bad. We drink the water there on the bridge all the time when it is cool enough. Drinking of the water hasn't made any of us sick that I know of. The water now is better. It hasn't got that gas or stench to it that it had before. It is more clear and it is purer I think.

CROSS EXAMINATION, By Mr. Jeffries.

Am a man of family. Have a pump at my home.

3231 Use the water from the pump for domestic and drinking purposes. There is quite a stronk current now. On account of the increased volume of water and better current I think the water is better. The water never foams in my boilers now.

RE-DIRECT EXAMINATION, By Mr. Todd.

I think it is because there is a better channel and a better current and because the water of Lake Michigan is purer than in this river.

RE-CROSS EXAMINATION, By Mr. Jeffries.

3232 I an't no analyzer or anything of that kind. I don't know anything about the effect that Chicago sewage has on the water. I do know one thing, that is I believe—well, I know it, that the water is better here than it was before.

J. P. BAUR, Examined in chief by Mr. Todd.

Am a fish culturist in the employ of the U. S. Fish Commission. Am at present in charge of the station at this point of the U. S. Fish Commission at Meredosia. I have been employed in that position about 14 years. I look after the collection and loading of the U. S. Fish Commission cars. Seven men compose the crew, not including myself.

3233 My duties give me an opportunity to become acquainted with the Illinois river. Up to five or six years ago, I had charge of the Steamer "Lotus" in making collection of fish for distribution by the U. S. Fish Commission. I became acquainted with the river from LaSalle to Grafton. The fish we handle for the U. S. Government are black bass, croppie, channel catfish and bream. There are lots of other fish that we handle as a collection, put up in formalin and send to Washington. Before the opening of the canal, the river between La Salle and Grafton, during the summer months, the water would get very low and the water was in what I would call bad condition. So much so that you couldn't drink it, even by the use of ice in the water. From Copperas Dam for about five miles above it, I have gone up that stream in the steamer "Lotus" and turned up sediment and dead fish and on several occasions there was a terrible stench and a man could hardly stand the smell, which I suppose was from the distilleries, or I believe it was the filth of the distilleries at Pekin and Peoria. (Motion by Mr. Jeffries to strike out.) I know that there were distilleries at Peoria and Pekin, but I didn't know there was a glucose factory at Pekin or Peoria. At low stages the water in the Illinois river would not affect fish so far as I know, in ponds. I don't know that it affected the fish below these dams any at

all, only during the winter season when the ice was over the water after the ice was broken up, we would find quite a number of dead fish. Those ponds I speak of are fed by the Illinois river when the water is high enough to go back into them. I have seen thousands of dead fish in these ponds. They were eaten by the different kind of water fowls that we have around this country.

3335 During the winter time I have noticed similar conditions as existed from Copperas Creek to Peoria, at La Grange locks. I don't know of any complaint ever having been made about any stench around LaGrange locks. At this point, before the opening of the canal there was nearly all the time a green scum on the water. We always had a current in the river. The channel would perhaps not be over 75 yards wide and vegetation would grow for about 100 yards from the channel bank to the east, to Meredosia. There would be a smell but I don't know whether you would lay it to the water or the fish. This is a great point along here for fishermen to throw off the offal of fish and it might have been that. That offal is thrown into the river at this point. The effect of turning the water of Lake Michigan into the Illinois river has been to make the water clearer and we have a three-foot high stage of water from low water mark. I could drink the water now in the Illinois river today if it had ice in it. I wouldn't have done so previous to the entering of the Chicago river, unless it was absolutely necessary to do so. I have noticed a green pod that floats on the water since the canal has been opened, but it isn't a scum. It might be taken for scum in looking at it from a distance. It seems to come from some tree or perhaps grows right in the water, I don't know. In my opinion the Illinois river has been greatly benefited by the opening of the canal.

3336 CROSS EXAMINATION, By Mr. Jeffries.

3337 During the hottest part of the summer, these dead fish are found in the lakes and ponds. The ice in the river didn't kill the fish every winter, only during a very low stage and when the ice was very heavy. It seems to be behind the dams.

Am a man of family. Have a pump or well at my house and use water for domestic and drinking purposes from the well. The carp is the most bountiful fish in the Illinois river.

3238 When I say the water is clear now, I give that as my opinion from the water being nearly perfectly clear nearly all the time during a fair stage of water. I do not know whether it contains deleterious matter or not, nor whether the sewage from Chicago gets here.

(AT LA GRANGE LOCK, ILL.)

JOHN D. KERR, Examined in chief by Judge Johns.

Am superintendent of LaGrange Lock. Versailles, Ill. is our postoffice. Have been superintendent for 21 years.

3239 LaGrange is called fifty miles from Kampsville lock. It is called six miles from Meredosia. These are not actual measurements. LaGrange Lock is 12 miles from Beardstown and it is 12 miles from Beardstown to Browning. The width of LaGrange dam between the abutments is about 837 feet. Since the opening of the drainage canal, the water of LaGrange dam has been raised, to the best of my judgment, I would say, four feet. That is shown by the gauges at the lock. There is one gauge above and one below the dam.

3240 At the present time there is a difference of 2.8 in the reading of the gauges. Prior to 1900 we used the water for drinking purposes and around the house. There was not as big a current as there is in some rivers. It wasn't as fresh as in other rivers at other times. There was a green scum—what we called water clover, on the river. It growed there. In low water it would be 20 feet wide some times. In times of low water, it was reasonably clear. You could see, I should say, a foot or a foot and a half at the dam. Since the opening of the canal the current has been a little over half faster.

3241 I haven't seen this clover groth on the river since. We have wells or cisterns at LaGrange. I don't drink the water of the river since we have had the wells and cisterns. The water is pretty near as clear as it was before. It has never been really as clear since I have seen it. I haven't observed any odor

unless it was caused by the drift accumulating. Since the opening of the canal I have noticed an odor anywhere around the locks. When the water was first turned in, it was very disagreeable here for eight or ten days. In damp weather now you can smell it very distinctly; the wind blowing it just right blows over to my house and I cansmell it.

3242 I think the most of it is caused where the water flows over the dam, stirs it and the wind blows it. I think that is where most of it comes from. When the water stands in the locks and the locks are consequently not flushing for some time, an odor arises, to a certain extent; it forms a kind of oily substance on top and when you open the valve and the water runs out and stirs it up, you can notice it very distinctly. It is different in that respect now, as to the time before the opening of the canal. I don't think there is any difference in the appearance of the ice.

3243 CROSS EXAMINATION, By Mr. Jeffries.

The water was clearer before the opening of the canal. That is my judgment, in fact I know it is. The stage of the water is about four feet higher than it was then. The depth of water that is flowing over the dam now is two foot three and the dam is 835 feet wide. At low water stages I had to keep one foot of water on the dam and used flash boards for that purpose.

3244 There has always been a good current since the canal was opened except when we had the high water in the Mississippi. It kind of slacked up. Before the opening of the canal the water didn't smell. Since the opening there has been considerable odor, at times worse than others. It is the same in the summer time. We don't get as much of it. One reason I think is because we are using the lock all the time and the water don't stand. It keeps going all the time, but whenever the water stays in the lock all the time then we can smell it

very readily and it has a scum and oily substance. It is a scum like formerly was on the river. I have shown the gentlemen some of it down there that was formed since this boat came through. I stated a moment ago that when the wind was in the right direction, this smell came over the dam but that is only at times when there is mucky water.

3245 I have a well and cistern at home but I use cistern water altogether. I dont use the Illinois river water because I don't think it is healthy. At least I imagine it ain't. A physician was down here a week or ten days ago, it was when I had found that bad cake of ice in the ice house and he advised me not to drink that water and told me to put the ice around the water in the receptacle and cool the water that way.

RE-DIRECT EXAMINATION, By Judge Johns.

The physician was Dr. Bley, Jr., of Beardstown. When I spoke of the water being clearer before the opening of the canal, I mean at all times except when a freshet.

3246 It doesn't clear up more rapidly since the opening of the drainage canal than before. It doesn't clear up as clear as it did before. It never gets clear. It hasn't been clear since the drainage has been in. It is about four miles from here to the Sangamon. The Sangamon comes in right above Browning and has three or four outlets above Beardstown Bay. It is about six miles from here to the mouth of Crooked Creek.

3247 When the Sangamon river rises, it makes the river here black and when Crooked Creek rises it makes the water yellow.

BENJAMIN COE, Examined in chief by Mr. Todd.

Live at LaGrange Locks. I commenced work at the locks here in 1882.

3248 We had a very slow current in this river before the canal was turned in and when the water would get low, of course it would get stagnant. LaGrange Lock was built with the calculation to back the water 50 miles. The dam raises the water seven feet four. In times of low stage of water, the lower the current gets the less water we would have and of course

above the dam, it would get stagnant. I have seen it get so low that I could walk across the river on top of the dam and the river would naturally have a green scum on it. There would be very little current. My judgment is that since the opening of the canal we have almost twice the current above the dam that we had before. I never notice any odor in the water here in the locks. Of course when it ain't disturbed there used to be a green scum came in the locks just the same, that is, it would be just the same as it would be above the dam, you know.

3249 Since the opening of the canal I have never noticed any odor in the water in the locks. It is the water that runs over the dam that I noticed the odor in. It was soon after the canal water was turned in. At the present time we never notice anything of that kind only when the water froze over close to the dam below and close above. I have gone under the water in diving apparatus.

3250 The water now would compare very favorably to what it was before in clearness. I think it is fully as clear now as it was before the canal was turned in and at times clearer. I have seen the water here since the canal was turned in the clearest I have ever seen it. I would think the water was lots cooler now than it was before. I have seen it when it wasn't fit for a man to go bathing but now it is most too cool. Since the opening of the canal I haven't noticed any typhoid fever any closer than say two and a half miles and that is along the bluffs and not along the river. I haven't noticed anybody having ague here for several years.

CROSS EXAMINATION, By Mr. Jeffries.

The water never freezes up against, above and below the dam and when the water would be frozen up and there would be an opening above and below the dam, I have noticed an odor since the opening of the canal.

3251 The government outfit here drinks cistern and well water. We don't have occassion to drink river water. We have well water which is colder. I don't notice any oily scum on the water here. The water gets foul around the locks

if it ain't disturbed. At this season of the year there is lots of fish and more or less dead fish in the water. People throw in many fish that they don't take and it makes the water rather foul around the locks when it ain't disturbed. I never noticed any odor before the canal was opened. I should judge the current is now double what it was before.

(AT BEARDSTOWN, ILL., July 20, 1903.)

G. W. BARNEYCASTLE, Examined in chief by Mr. Todd.

3252 Live at Beardstown. Took samples of Illinois river water at this point for sanitary district of Chicago to be sent to University of Chicago and to the board of health of Chicago in 1899 and 1900. (Witness explains method pursued and times and places where samples were taken.)

3255 DR. GEORGE BLEY, Examined in chief by Judge Johns.

3256 Have been practicing physician 22 years; have practiced in Beardstown 21 years. Have had a general practice among the people of this vicinity during that time. Beardstown has a population of 15,000. The water supply is obtained from a six or eight inch well driven ninety feet into the sand, about 10 or 11 blocks from the river in the back part of town. Before the opening of the canal the Illinois river had less current than it has now. A scum formed on the river and I have noticed odors at times. I rather think I have noticed that odor since the opening of the canal, but I wouldn't be sure.

3257 I would consider the water at this point as better than it was. There has been typhoid fever in this vicinity, among all classes of people. Typhoid fever has been increasing here probably for the last ten or fifteen years. During the last three years I have had ten, twenty or may be 30 cases. I think though at least thirty under my observation. I have had cases from among people who drink from the public water supply and from the Illinois river. In my practice the dejecta is disinfected and buried.

3258 I could not say what the practice of the other physicians here is in that respect but it is my impression that they do likewise. Since the opening of the canal there hasn't been this stagnation which I previously observed. We have had higher water since.

CROSS EXAMINATION, By Mr. Jeffries.

The current has increased, I should say. The number of cases of typhoid fever has increased to some extent since the opening of the canal, and before. It has been increasing for a good many years. I don't think they have increased any faster since the canal was opened than they did for the last ten or fifteen years.

3259 There has been a gradual increase. I think the people in this town pretty generally use the water from this public supply. There is a portion that have wells, perhaps half of them. I don't think the people use the water from the river to any extent for domestic and drinking purposes, possibly these people living along the river in the cabin boats do, but otherwise I don't think it is used at all. When I say the water is better I say so from appearances mostly. It is clearer under the same conditions than it was before. Before and since the opening of the canal I have noticed at times a greasy and oily appearance to the water.

3260 L. W. GOODELL, Examined in chief by Judge Johns.

Live in Beardstown. Am in wholesale and retail ice and fish business. Have been in the ice business since 1887 and in fish business about seven years. We buy fish from fishermen and run a seine also. My partner, George Swan, engages in the seining.

3261 Prior to the opening of the canal, the water would get pretty low at times. The current was quite sluggish and the water somewhat riley—dirty looking, not very clear looking. I have noticed a green growth—a sort of small vegetable with two or three leaves, a little short root that would form in large masses over the surface of the water. I don't

recall whether there was any odor to it in the summer time. I have noticed it in the winter time when there were holes cut in the ice. There have been times when a great many fish died in the winter time, when there was ice on the water. I don't know exactly what I attributed this smell to, except the sewage from Peoria and Pekin. I think it was that partly. It is 80 miles to Pekin and 90 miles to Peoria and 50 or 60 miles to Copperas Creek dam. Before the opening of the canal we cut the ice from the waters of Muscoopin Bay, from the arms that project off the river above the C. B. & Q. bridge. That water is derived both from the Illinois river and from surface water that drains into the bay at the north end of it.

3262 As I recollect it, it was at least two winters that the fishermen complained largely of the fish dying and several times we have noticed an odor coming from the water under the ice, prior to the opening of the canal. Since the opening, I haven't noticed this green growth in the water. I have cut ice and put it up since the opening. I didn't detect any odor from the water during the last three years and the fish did not die under the ice in the last three years to my knowledge. I haven't noticed any difference in the ice cut in the last three years. The water looks clearer now than it did before.

CROSS EXAMINATION, By Mr. Jeffries.

3263 I don't drink the water from the Illinois river. The town here is supplied with water from drive wells. In the winter time we drink water from the river when we are cutting ice. The deepest point in this bay, when the ice was being cut, was about 16 feet.

3264 Before the opening of the canal I have noticed an odor on the water. I noticed an odor when we cut a hole through the ice. I have not detected the odor since. Since the opening of the canal I have noticed an oily substance along close to the shore. I can't say that I have detected any out in the bay or out in the body of the river.

H. EHRHARDT, Examined in chief by Mr. Todd.

Live in Beardstown. Am a physician. Have been practicing 36 years. Am health officer.

3265 Am acquainted with the Illinois river within a radius of ten or 15 miles above and below Beardstown. Before the opening of the canal, the river during low stage was often covered with a vegetable growth, a sort of fungus, grass and also a scum. The current during low stage of water was very sluggish. Since the opening of the canal so far as external appearances go, the water has had a better appearance, is clearer and it has been devoid of that vegetation which was observed before. I have observed no cases of typhoid fever before or since the opening of the canal. I do not know of any people having died of typhoid fever in the last four or five years in Beardstown. I don't know of any typhoid fever existing in this territory now, or within the last two or three years.

3266 The health of the people along the river is better than that of those living in the foothills or the high lands. I have noticed no difference as to malaria. I have had cases of typho-malarial fever, so designated. I consider typho-malarial fever a malarial fever that, owing to intestinal irritations assumes a typhoid character.

CROSS EXAMINATION, By Mr. Jeffries.

I know nothing of the water's internal conditions. The water is not used here generally for domestic and drinking purposes, excepting after it is filtered. We know that the water that is obtained from these public drive wells is river water because the water rises to a level in these wells to the same height as the stage of water in the river.

3267 These wells are all over the town. Without filtration I don't consider this water in the Illinois river suitable for domestic purposes. I consider that by our driven wells the water is perfectly filtered. I think the current is more rapid since the opening of the canal. I haven't noticed since the opening of the canal a greasy, oily appearance to the surface of the water.

3268 ED F. HARRIS, Examined in chief by Judge Johns.

Reside in Beardstown. Am in the fish business. Cover a terirtory of pretty near all the river from Peoria down below Kampsville. Before the opening of the canal the water was not as clear as it is at the present time. We always had through the month of July and August a green scum on the river and in the winter time we could cut open holes in the ice and there would be a gas smell from it. The mud and moss on the river would gather on our nets. I drank the water at that time.

3269 Since the opening, the water has been very clear and I think it has been in better shape except winter before last. It clears up a good deal quicker. There has been this green scum on the water in the summer but not so much before. Since the opening, we find a slime on our nets. It is a white substance as near as I could give it, like where you boil pigs' feet together—gelatine. It is very hard to get off; it is very near a whitish color. It forms in strings and hangs down from the nets. I use considerable ice and the ice has been good. I don't think it could be any better than what we have got here. It is as clear as crystal.

3270 It is taken from the bay above here and forms from the river water. The fishermen when on the river drink more or less of the water. I don't know of any typhoid fever in the last three years among fishermen. As a general thing they have got good health.

CROSS EXAMINATION, By Mr. Jeffries.

There has been some scum on the river nearly every summer during the months of July and August. It is hardly an oily, green scum now, not as much as it used to be. I don't know whether there is deleterious matter in the water or not.

3271 Unless the river overflows its banks there is no current in this bay.

MARTIN McDONOUGH, Examined in chief by Judge Johns.

Live at Beardstown and run the Park Hotel. Have lived here all my life. During the fishing season fish with line and

nd on the river several times a week. Before opening of the canal there were 15 or 18 inches less of water. I noticed in the fall we had a scum on our water that we don't have now. I don't know very much about that. I don't see any dif-
3272 ference in the ice. The ice that we use comes off the bay and that water is usually always clear.

CROSS EXAMINATION, By Mr. Jeffries.

This ice is cut from the bay up here where the water is still and deep. During low water there is very little water from the river gets in. It is really part of the river, only the current doesn't get over there and it leaves the water dormant. I don't know whether the water contains deleterious matter or not. I don't use it in any way.

THOMAS K. CONDIT, Examined in chief by Judge Johns.

3273 Have lived in Beardstown since 1874. Am cashier of the First National Bank. Before the opening of the canal during low water stage we had what we regard as a very bad condition here—very stagnant water during August, September and October. In fact, a greater portion of the time there was a green scum in front of the city here all the time. Since the opening of the canal my opinion is that we have a much better condition of the river than before. There is no smell to the river and no green scum on the water. Before the opening of the canal it had an odor, smelled more like rotten fish than anything else. I don't notice that now.

3274 So far as my knowledge goes, there has been very little typhoid fever either before or after the opening. Occasionally we hear of a case, but very seldom.

CROSS EXAMINATION, By Mr. Jeffries.

I haven't noticed any of this odor since the opening of the canal. Don't use the water for domestic or drinking purposes. We have a great many drive wells in town. When I say the water is better now than it was before the canal was opened, I am basing my statement on the general conditions, that is as it appears to me.

3275 Of course there is a stronger current and we have had higher water all the time consequently there has been a greater volume of water passing down the river.

G. P. HOLLINGSWORTH, Examined in chief by Judge Johns.

Reside in Beardstown. Am fireman on the C. B. & Q. out of here. Formerly lived at Browning. Had a fruit farm there. Was engaged to take samples of water from the Illinois river. Made arrangements with J. A. Harman and Dr. J. H. Long in 1899 and 1900. (Witness states places where samples were taken and method pursued.)

(AT HAVANA, ILL.)

HAROLD G. HEBERLING, Examined in chief by Mr. Todd.

Now live in Easton, about 13 miles east of here. Formerly lived in Havana. Took samples of water from the Illinois river for the sanitary district of Chicago in years 1899 and 1900. (Witness states places where samples were taken and method pursued.)

3286 O. H. HARPHAM, Examined in chief by Judge Johns. Am postmaster at Havana. Have lived here 58 years. Have been acquainted with the river all my life.

3287 Before the opening of the canal in low water the river was very foul. At times, extremely so. I have in mind noticing that large islands of floating manure came down. Prior to the time I was appointed postmaster there was a large island of floating manure and offal, which I thought was from the Peoria distilleries, lodged against the pier of the wagon bridge. My attention was called to it from the fact that at that time I was one of the directors of the Illinois Bridge Company. We were fearful that it would injure the bridge and in attempting to remove it, we used common blasting powder. We were unsuccessful in that and finally removed it by prying and nicking off pieces until the current swung it around and took it through, but it was so large that it was impossible for it to go through the draw of the bridge. (Objected to by Mr. Jeffries.)

At low water there was a certain scum on the river and it was so much in evidence that you could see the wake or track of a boat. That wasnt always so but it was occassionally so.

3288 At times there was a smell. At low stage and in warm weather it was very offensive. I have noticed it at my place of business and at my house four or five blocks from the river. Since the opening of the canal I haven't noticed anything of that kind. I don't think there has been what you would call a scum. In my opinion the water is in better condition now than it was before, that is ,at the same stage. I have not heard of a single case of typhoid fever since the opening of the canal among people using river water. I am pretty generally acquainted with the people of this community. We have no delivery system, the people come to the postoffice for their mail.

We have a drive well system of waterworks.

3289 We have only a partial sewage system, the sewer empties into the river. The sewer only reaches up into the business part of the town a little ways, not very extensive. One-third to one-half of the people use the water from the public water supply. The other people obtain their water from drive wells and pumps. There are very few open wells. The population is 3,400 or 3,500. Havana is 18 miles from Copperas Creek Locks. LaGrange is I should think 40 or 50 miles from here. It is 41 miles from Peoria by rail.

CROSS-EXAMINATION, by Mr. Jeffries.

3290 These sand wells that belong to the town are located seven or eight blocks from the river. The soil through which they go, from the surface down, is as follows: A few feet on the surface is what we call soil, from there to the bottom, as far as we have gone, is sand and gravel with occasional streaks of clay here and there. Those streaks of clay are small, sometimes only an inch or two, or a foot or two through. The people of Havana don't use the river water for domestic and drinking purposes. I don't consider this water good for domestic and drinking purposes. I don't consider any open river

water, river or pond or anything of that kind, proper water for domestic purposes.

3291 The current is considerably greater now than it was before.

GEORGE W. BUNKER, examined in chief by Judge Johns:

Am an upholsterer and reside in Havana. Have lived here twenty years. Have lived on a boat on the river quite a while. Used to be employed on the steamboats. Before the opening of the canal the condition of the water was very bad indeed in very low water. The water was so impure that they talked a great deal then about blowing out the dam, thought they would get better water by cutting a waterway out and letting the water pass off quicker. There was an odor in the water and there was a green scum sometimes in places where the wind did not blow it away. I have made the remark several times that if it was not for the steamboats running up and down the river, the people could not live on it. Steamboats agitating the water, naturally purify it a little.

3292 Through the ice it wouldn't do to drink the water at all. I have tried it and know something about it. When the water was covered with ice and a hole was cut, as a general thing there was an odor from the water, you could smell it. There was a good many fish died but we laid it to the Pekin and Peoria slop, or something coming down the river that killed them. Since the opening of the canal the water has been far superior to any water we have had since I have known the river. It has been better, purer and sweeter. We don't get none of that bad smell now we used to have so much. I don't use the water now myself. It is a little too muddy of late. There is a lake and the Spoon river right across here sends out a good deal of mud and muddies the water here. Spoon river comes in here perhaps a quarter of a mile up the river. I don't know of any typhoid fever since the opening of the canal. I don't think there is any at all. There is a good many people living right on the river and I know that there is no typhoid fever. Before the opening

of the canal there was times we had a good deal of fever, ague and chills, but that seemed to disappear. We don't see that now.

3293 CROSS-EXAMINATION, by Mr. Jeffries:

People in town use hydrant water mostly.

3294 They don't use the water from the river for drinking purposes as a general thing. I say the water is better now because it smells better. It hasn't got that bad offensive smeell like it used to have. You would naturally suppose of course that it was the flow of water that remedies that. I don't know whether filth is in there now or not. I know the water is a little better now, that is all I know. I don't know what it contains. The current is much stronger now than it was before the canal was opened.

3295 C. M. MORRILL, examined in chief by Mr. Todd.

Have lived at Havana ten years next January. Am a physician and surgeon. Before the opening of the canal we had very low water. It was a filthy bank all along, scum and filth all along the banks, a good deal of odor to it so you could smell it clear up town sometimes. There used to be cakes of

3296 filth that came down from Peoria. There was one at the bridge that they had to dynamie out. There was a large island came here one time and lodged at the bridge and they tried to blow it out. There was a green scum here every summer. The opening of the canal has made more current. The water has not been so low during the summer. The water looks purer and cleaner and the banks have been much better and there is no stench as there was before. In times of sudden freshet, before the opening of the canal, the river would be cleared out and there was less malaria in those seasons when we had high water and less typhoid-malaria. We have had very little here since there has been high water here. Since the opening of the canal I haven'tt seen any real typhoid here.

3297 CROSS-EXAMINATION, by Mr. Jeffries:

There was some typhoid before the canal was opened. I haven't seen any cases here since. The water of the river is only

used for drinking purposes by the fishermen I guess. They tell me they use it. I have seen them drink it. I don't consider any river water good for domestic purposes where cities drain in it. I wouldn't drink any river water, I have, though. I wouldn't unless I had to. I wouldn't recommend it for drinking purposes. I have drank it on these excursion boats when they had ice in it. I wouldn't be particularly afraid of it but I would rather have better water.

3298 L. A. EVERIST, examined in chief by Mr. Todd.

Have lived in Havana 30 years. Have been a fisherman all my life. Before the opening of the canal the water got very low during this season of the year (July) and got very filthy. During the cold season the water seemed to be more filthy. During the season when it would be froze up, it would smell bad. In the summer there was scum on it, a green scum. It would

3299 kill the fish in the winter time. After the river would be frozen up for some time the fish would have to go into the spring water or they would die. They would get weak, they would swim along the edge of the river and people would pull them out with gigs or forks or something. I have seen them condemned in the St. Louis and New York markets. If you cut a hole in the ice there would be an awful smell and the water would be very filthy. There were what is known as Peoria islands floating down the river. They were composed of manure. I have seen them all the way from this place to Peoria, they would vary in size all the way from two or three feet to 50 feet.

3300 I have seen them here at Havana. I saw a large one lodged against the bridge here that I know was blasted loose. Since the opening of the canal the nets last longer. The water is more cool. This slime or stuff that collects on the nets comes from the stills at Pekin and the glucose factory I suppose. It is a slimy substance and will stick to anything it touches. It flows in small pieces but will collect in large quantities on anything it touches. We call it slur-gut among the fishermen. We had it before the opening of the canal. The nets are cleaned

from the effects of this slur-gut by shaking them and taking them to the bank and whipping with sticks. It is a kind of white color. I fish between here and Kingston.

3301 I find that substance on my nets up that far. There is not much difference as to the quantity we find now as compared with the quantity found before the opening of the canal. The opening of the canal has made the water higher and the water has been cooler and purer and not much smell to it. In the fall of the year as the water begins to get cooler, it is stronger and there is more filth near Peoria than there is near this point. The slur-gut can scarcely be noticed in summer. It don't have a tendency to float in the warm weather.

CROSS-EXAMINATION, by Mr. Jeffries:

3302 Have an open well at home. These Peoria islands come down the river during the spring season. At times they are frozen. They come since the opening of the canal and travel a little faster. I drink the water of the river when I am fishing in the spring. I don't drink it when I can get anything else to drink, though.

3303 We have more current in low water than we did before. I notice very slightly the oil scum on the river now. It has a mossy appearance. I do not know positively that these Peoria islands come from Peoria. I always heard so. The fish are all thriving well. The carp does the most well. They will feed on almost anything.

SAMUEL F. KYLE, examined in chief by Judge Johns:

Reside in Havana. Am in the ice business.

3304 Have been in that business for nine or ten years. Took samples of water at this point for J. H. Long and for the State. (Witness states places where samples were taken and method of shipping, etc.) The ice we have taken here 3307 has been the same before and since the opening of the canal because we have taken it out of the bay here. As 3308 far as I know the water is better now than it was before. There is more current and less stagnation about it.

CROSS-EXAMINATION, by Mr. Jeffries:

Am a married man. We use hydrant or well water at home. Haven't to my knowledge, since the opening of the canal, noticed the oily greasy substance of coloring on the water. The current is quite a good deal swifter now. We have a good current at all seasons of the year. The lake from which ice is cut is called Cook Harbor.

3309 It is fed by springs and by the flow of water that comes down from Quiver Creek. Year before last we cut from Seid's Lake, about 200 yards from the river. Seid's Lake is fed from Thompson's lake I think and from the Illinois river. Thompson's lake is fed from Thompson's river and from the Illinois.

3310 JOHN McGARVEY, examined in chief by Mr. Todd:

Live at Havana. Have fished for 26 years on the Illinois river. Before the opening of the canal, the condition of the river was pretty poor. I don't think if the Drainage canal hadn't been turned in here we would have had half the fishing we have got now. The water was dead, kind of rotten and smelled at low water.

3311 There was an odor at low water mark. That odor extended from here to Peoria. There wasn't any scum without the water was right low. As you went from Havana towards Peoria the water got worse. The distilleries at Peoria and Pekin were the cause of it. After you passed Peoria it got better. That condition prevails as far as I ever was along it, and that was as far as La Salle and Peru. Since the opening of the canal the water has been better.

3312 The water is purer than it was before. There is a current through it and it is purer. If you cut a hole through the ice in the winter time there is a smell to it but not as bad as it was before. I have run across slur-gut. We thought it come from those distilleries at Peoria. There ain't none of it above Peoria. We have that stuff yet but I don't think it is quite so bad since we got the current in the river. I never see that substance above Peoria. I have seen Peoria islands floating down

the river, some pretty good sized ones, too. Some 30 or
3313 40 yards large. They are composed of hay and manure.
They all say they come from the still houses at Peoria and Pekin. I never saw any above Peoria.

CROSS-EXAMINATION, by Mr. Jeffries:

I never saw one of those Peoria islands in the summer time. When I say the water is purer I mean it ain't dead. There is a good current through here and it keeps all trash and everything out. That trash all goes down the river or else back, I don't
know where it goes. If you cut a hole in the ice in the
3314 winter, you can still smell the water a little. The current
is much stronger than it used to be. All fish thrive well here. Carp is the most plentiful. They feed on flags and roots and things. They feed on most anything. I don't use water from the river at home. We use water from the hydrant. When it is coid in the fall and spring and winter, we use river water
for domestic purposes.

3315 ERNEST O. SPINK, examined in chief by Mr. Todd:

Live in Chandlerville. Took samples of water for the Sanitary District. (States method and places where samples were taken.)

3317 RICHARD L. ENGLAND, examined in chief by Judge Johns:

3318 Reside in Havana. Have been a fisherman over 30 years. Have lived in Havana over 50 years. Have fished say 20 miles above and 20 miles below here. I employ men and fish on a large scale. Prior to the opening of the canal, in our early fishing here, we used to fish altogether with bait nets and seines and the sediment or settling was so bad we had to quit that kind of fishing. There were substances floating here. The main body of it was corn. It would fill the nets full and we had to crab it out with a widlass. When the water got cold it would form on there like cotton, it would collect on the nets and the meshes

were all full like a blanket. There was more smell when it was froze up than any other time. We would cut holes in the ice and could hardly stand it over the holes in winter; we would raise the nets and the fish in the nets would be dead.

3319 Since the opening of the canal the water has been a good deal better. We went back to the same kind of fishing that we did then but we had to quit. We don't get near so much of that floating stuff as we did before. More current makes the water purer. The floating slime on the water came from Pekin and Peoria. The sugar refineries and the distileries I think is what caused it. It wasn't at that time above Peoria. I was acquainted with all the fishermen there and they claimed they were not bothered with it above there. I can't hardly mention a fisherman that ever had typhoid fever. We have fish now for a week in the live boxes and before, in hot wetather, they would die in one night.

CROSS-EXAMINATION, by Mr. Jeffries:

The current is much stronger now than it was before the canal was opened.

3321 We have a nick-name for that substance, and call it slurgut. We get the substance now since the canal is opened, but it is only just a short time. We get rid of it quickly; if there is any in the river, just a little of it will come down. We don't use the water of the Illinois river for domestic purposes at home. In winter time when we are fishing and the water is cold enough, we don't use any other than the river water.

GEORGE E. McHOSE, examined in chief by Judge Johns:

Live at Havana.

3321 Have lived here permanently since 1872. I run a boat livery and am mayor of the city. I think this is my seventh term. Before the opening of the canal the river was dirty and stagnant and everything else and had a bad odor. Since the opening, the water is in a great deal better condition. Before the opening there was a kind of slime in the water and now there is not much of it. There is some. I don't know of any typhoid fever in this vicinity since the opening of the canal.

CROSS-EXAMINATION, by Mr. Jeffries:

3322 Don't use the river water for domestic purposes except for washing. We have a cistern. The current is swifter and we have more water now than before the canal was opened. I don't know whether it contains deleterious matter or not. All I know about it is from observation. The fish and turtles and stuff used to die before the opening.

PHILIP L. DIEFFENBACHER, examined in chief by Mr. Todd:

Am a physician and surgeon. Have been practicing in Havana for about 48 years. Before the opening of the canal the river got very low and since the dams were put in, there is a good deal of deposits along the shore. There was a scum on the water at low tide and an odor. The opening of the canal has improved the condition of the river. Before the opening of the canal the river I think caused malaria. Since the opening of the canal there has been no typical cases of typhoid in Havana.

3324 CROSS-EXAMINATION, by Mr. Jeffries:

We have a splendid water system here. We get the water from drive wells. The people in Havana don't use river water for domestic purposes. Never analyzed the water. I don't recommend the river water for drinking and domestic purposes. It never has been fit to use. The current in the river is much more rapid now than it was before the canal was opened. It don't seem to me that there has been much odor lately. I don't think I have noticed it this summer at all.

3325 (AT PEKIN, ILL.)

C. G. HERGET, examined in chief by Judge Johns:

Live at Pekin. Am manager of the Globe Distillery. We are engaged in distilling alcohol spirits and whiskey made from grain, corn about 90 per cent, rye and malt about 10 per cent. The distillery was in operation in the years 1900, 1901, 1902 and thus far in 1903. In connection with the distilling, cattle were fed from the refuse.

3326 With reference to the city of Pekin, the cattle are fed a

little below. We are below the city. After the operation of distillation is completed, the residue is called slop. In a bushel of grain there are so many gallons of water; Uncle Sam takes 56 pounds to the bushel on all grains—wait a minute; now there are 45 gallons of water to the bushel mashed, so each thousand bushels of grain represents 45,000 gallons. This product after the distillation of the spirits, constitutes what we call slop, so that for each thousand bushels of grain, in distilling there are substantially 45,000 gallons of beer. This beer is then distilled, after which there remains about 40,000 gallons of slop.

3327 It is stored in tubs and from the tubs it is fed to cattle through a trough three times a day and divided equally about three pecks to a steer per day, which would be about 11 gallons to the feed. The barns are located about one-half mile from the river. The construction is entirely wood, with proper ventillation and sewage connection. Each steer has slop three times per day and roughness twice per day, salt twice a day and the barns are thoroughly cleaned with cold water twice a day. We feed 440 head of cattle under one roof. What we call roughness is hay or straw or cotton seed hulls.

Q. When the sheds are washed up, what becomes of the washings?

MR. JEFFRIES: The question is objected to for the reason that it is incompetent, irrelevant and immaterial, not proving any issue involved in the case, it being immaterial so far as the issues of this case are concerned, what the volume or extent of sewage matter or offal from cattle pens at Pekin, into the Illinois river, are, and that such deposits are not and cannot be under any circumstances a legal or equitable defense or a justification of the right or privilege to Chicago or the Sanitary District of Chicago to make such deposits or deposits of any character, whether sewage or otherwise, into the Chicago Drainage canal and thence into the Illinois river. And for the further reason that Pekin is situated upon the natural watershed of the Illinois river, and the fact of discharging decomposing matter

from distilleries or other sources from cities and places upon the natural watershed of the Illinois river does not and will not either in law or equity, entitle the city of Chicago and the Sanitary District thereof to deposit its sewage, filth and other deposits into a stream carrying said deposits into the Illinois river by means of artificial canal or waterway, when said deposit naturally belong to and flow into, the basin of a watershed other than that of the Illinois and Mississippi rivers, and for the further reason that there is no evidence showing that the deposits into the Illinois river from the distilleries and cattle sheds of Pekin contain deleterious matter or matter injurious to the public health or to the health of those consuming the water and there is no evidence showing that such substance contains disease germs, or the bacilli of water-borne diseases.

It is herby stipulated and agreed between counsel that the foregoing objection shall be considered as having been made to all testimony as to deposits in the Illinois river below the Bear Trap Dam and may be raised at any time in the argument of the case without renewing the objection at the time any witness may testify.

F. S. BRIGHT, Com'r.

A. They go into the Illinois river. When the sheds are washed, the urine and manure from the cattle are washed out and flow into the Illinois river.

3329 The cattle are fed through troughs which are also washed out. The roughness is fed in hay alleys which are cleaned twice per day by scraper. These matters go into the sewer and are carried into the Illinois river. This refuse from the cattle sheds forms an island, in the Illinois river, composed principally of manure, hay, straw, and refuse. The cattle are fed salt twice a day, about a quarter of a pound to a steer per day. If any remains, it would be washed into the sewer.

3330 Q. You mean that there is about eight or ten gallons of urinary discharge per steer per day, and that the local discharge would be about half that amount, about four to five gallons?

A. Yes sir. There would be about 160,000 gallons of water per day used in washing out the stables. These islands that are formed in the river are cast adrift and allowed to take their course. This is done about once a year. Before it goes away, it is covered or left exposed to the air. We were feeding cattle continuously during the year 1900.

3331 We fed during that year about 5,000 head, from Oct. 1st to June 1st; that year we fed 4200 head per day and from June 1st to Oct. 1st about 2300 head per day. In 1901 the variations would not be over 400 or 500 head. We feed every year about the same we fed in 1900. It may vary from 150 to 200 head. There are other refuse products of distilleries than those described. They are hot and cold water used for cooking, in the boilers, and for cooling purposes. I don't think these waters contain any foreign substance nor any organic matter. The water used in the distillers is obtained from drive wells and open wells of about 80 ft. depth. We feed about 8 lbs. of roughness per day per steer. In 1900, 1901, 1902 and thus far in 1903 we have had two distilleries in operation in Pekin.

CROSS-EXAMINATION, by Mr. Jeffries:

We don't use the water from the river for any purpose. The Globe Distillery has been in operation here since 1893 and operated until 1898 by that name, then was sold to the Standard Distilling and Distributing Company, with home offices at No. 27 Williams St., New York. The plant was operated from 1893 to 1898 with 4,000 bushels eigth months in the year and 2,000 bushels the remaining four months, per day. The cattle industry during that period was the same as I stated a little while ago.

3334 The capacity of the plant and the output both as to distilled product and cattle has been about the same from the day the plant was built in 1893 to the present day, subject only to slight variations. There is no offal or products not used in the distillery that is thrown into the Illinois river, aside from what is fed to the cattle, to my knowledge. The offal and the unused roughness is scraped and then washed into the sewer

and then flows into the Illinois river, forming an island. The mouth of the sewer is above the surface all the time. It is an open sewer. This material forms in a heap at the mouth of the sewer. It doesn't act like other manure, it is entirely different. We don't feed anything except perfectly sound and healthy cattle and we keep them in that condition

3335 They are about three or four years old. The steers will average about four years. We don't use any chemicals of any kind in our distilleries. Pekin has a water system. It gets its supply from driven wells and doesn't use water from the Illinois river.

3336 C. G. MUEHLMANN, examined in chief by Mr. Todd: Have lived in Pekin since 1900. Am a physician and surgeon and health commissioner of Pekin. The source of the water supply of Pekin is drive wells. They are pipes driven into the ground about 150 feet and from there piped over the city and the water is piped into a tank, that is where we get the pressure.

3337 The main sewer of the city is four blocks long, and they have some sewers in four blocks of alleys that connect with the main sewer that empties into the Illinois river. I was born and raised in Pekin and went to Chicago in 1886. Studied medicine from 1897 to 1900 and during that time was in Pekin at intervals. Before the opening of the canal the water was more sluggish, there was more green scum and filth on the surface of the water. The current wasn't as swift as it is now, and I think the opening of the canal, or the water coming in from Lake Michigan has deepened the channel. The water is clearer now than it was at that time.

3338 The deaths from typhoid fever for 1900 were 2; for 1901, 1; for 1902, 2 and for 1903, up to July 1st, 1. Those are the statistics I furnished to Mr. Unger, the representative of St. Louis, who called here. I don't know the history of the cases, but they occurred in the city.

CROSS-EXAMINATION, by Mr. Jeffries.

I gave Mr. Unger the deaths for 1897, 1898 and 1899. I

think we ran back ten years, but the books were in very poor condition. I don't know whether I gave him a statement that could be relied upon as authentic prior to 1900.

3339 There are a number of private driven wells in town. Most every one has a cistern of their own. The population is between nine and ten thousand. The people in Pekin don't use the water from the Illinois river for drinking and domestic purposes. I don't believe they ever used it. I have not made a scientific investigation of the water. The water is somewhat clearer than it was before. All the clear water is not necessarily free from harmful effects. All cloudy water, or of muddy appearance, is not necessarily disease laden. I believe the current is much swifter since the opening of the canal than it was before. I would not recommend the water of the river for drinking purposes. I would recommend it for domes-

3340 tic purposes. I don't believe any river water ought to be used for drinking purposes without cooking.

D. H. JANSEN, examined in chief by Mr. Todd:

Live in Pekin. Am city enginner also in the brick and tile business. Collected water for the Sanitary District of Chicago in 1899 and 1900. (States method employed and places where samples were taken.)

3344 H. G. HERGET, examined in chief by Judge Johns:

Am a manufacturer and reside in Pekin. Was connected with an establishment for the manufacture of beet sugar, commenced in this town in 1900 and 1901. Continued two years, and about two months each year. Manufactured several million pounds of beet sugar during those two periods. The refuse material was beet pulp, some of it was run through sewers into Dead Lake and some of it was fed to cattle. Dead Lake is in the southwestern limits of Pekin, about 1,500 feet east of the

3345 Illinois river and has an outlet into the river. When the river is high the water backs into the lake. When the river is low, the waters from the lake flow into the Illinois river. In the manufacture of beet sugar we use an infinitesimal percentage of muriatic acid. Deducting the water which would

evaporate we deposited six thousand pounds of beet pulp in Dead Lake in those two seasons. The form of beet pulp as it comes from the diffusion batteries is similar to macaroni. When it is dried, it is like hay, it is fibrous. When it is deposited in Dead Lake it is more of gelatinous nature. It is that part of the beet from which the sugar and solids have been extracted. When floods come into the Illinois river some of this material was washed out into the Illinois river.

3346 In the manufacture of sugar we deposited water in Dead Lake which contained lime and other solids in infinitesimal quantities. We used and passed through our sugar refinery possibly one million gallons of water per day, which was discharged into Dead Lake, and which passed into the Illinois river, if not evaporated by the sun. This was deposited through a sewer, so that mixed with the solid matter during two months of each year there was also one million gallons of water a day. During the time the sugar was manufactured there was a sluggish stream flowing from Dead Lake into the Illinois river.

3347 I hardly think the solid matter was carried out into the river excepting what little pulp was carried. Some of the pulp remained in the lake and some got into the river. After the close of the factories as a beet sugar concern, it was converted into a glucose factory, in June 1901. I am a director of the Corn Products Company. In the modern manufacture of glucose as now produced in Pekin, there is no refuse. All solids in the corn are recovered and all that runs into the lake is water, possibly two or three million gallons each 24 hours.

3348 It contains a nominal per cent of sulphuric acid, a moderate fraction of one per cent per thousand gallons of water. The water from the Glucose factory runs into the Illinois river from Dead Lake. The manufacture of glucose is still continuing. At times there is a discharge from a glucose factory of a whitish or yellowish color, when filter cloths burst or tear. It is apt to consist of a very small per cent of gluten. This rarely occurs at Pekin.

3349 In the event it does occur only such a small amount goes through as would pass through a small rip in a filter cloth and on many occasions, repairs are immediately made.

CROSS-EXAMINATION, by Mr. Jeffries:

There are no other glucose factories in Pekin.

3350 There is one other at Peoria. I don't know of any other on the Illinois river. They manufacture glucose, grape sugar, corn oil, feed, oil cake and starch at our glucose factory. In the manufacture of these products from corn, there is no substance or material or solids from the corn wasted. We use sulphur and acid in the manufacture. The sulphur that is in the water escapes. It is a very small percentage as compared with the amount of water.

3351 The amount is enough to be a good disinfectant, I know. None of the acid escapes. The solids lost in steeping were carried into Dead Lake until some few months ago, since which time they are being evaporated. We get the water that we use from the Illinois river for the boilers and pump it from the ground for manufacturing.

E. W. WILSON, examined in chief by Judge Johns:

Am president of the American Distilling Company and of the German National Bank at Pekin. The name of the distillery we manage here is the American Distilling Company.

3352 It is about a mile and a half below the centrol portion of the city and on the bank of the Illinois river. We manufacture spirits and alcohol generally. We have a mash made of corn principally and some malted barley and rye. Before we commence to distill we have a product called beer. After the distillation of this beer and the alcohol is extracted, the remainder is called slop, the quantity of which we estimate by the bushel. About forty gallons of beer or mash is equivalent to a bushel of grain. After the alcohol is extracted, we feed the slop to cattle, which are located on the same premises, on the bank of the river, in sheds on the distillery premises.

3353 When the distillery is running at full capacity we feed 4,000 cattle from the refuse. The cattle are tied in sheds

to a trough in which the slop is run. We feed the cattle three times a day, about a third of a bushel, or about 12 to 15 gallons each time. If there is any slop left, it is run out on to the bank of the river. We also feed the cattle some hay and cotton seed hulls, which is fed to them dry. If there is any remainder from that food, it is carted away in wagons, generally. They use it for bedding the cars. We keep the sheds clean by men going in behind the cattle and scraping the excrement into a sewer and it is washed out by the water, which goes out on the bank. I suppose the water gets into the river, but most of the excrement would remain in the low land on the banks of the river. We clean the streets twice a day.

3354 I haven't any idea how much water we use in cleaning, probably 50,000 gallons each time, or 100,000 gallons per day. It might be double that amount, I don't know that I could estimate it. The refuse below the distillery on the bank of the Illinois river forms a mass of hay and manure. In times of high water a large portion of it floats away down the river. It washes away itself, under the influence of the current. During 1900, 1901, 1902 and thus far in 1903, the distillery has been running all the time and all that time we have been feeding cattle with slop and hay and throwing the washings of the cattle sheds and manure on the bank of the Illinois river.

3355 There is from 12 to 15 gallons of urine from each animal and from 40 to 50 pounds of excrement. We feed these animals about a barrel of salt a day. I don't think we feed them as much as a quarter of a pound each per day. About 6,000 head of cattle have been thus fed at the American Distillery in each of the years 1900, 1901, 1902 and thus far in 1903. We feed about 4,000 at one time. There is no other refuse material from the distillery than slop. 500,000 or 600,000 gallons of water are used for cooling purposes in the distillery which afterwards gets into the river.

3356 There is about 200,000 pounds of excrement per day. Dead Lake is east of our distillery. It is a lake which empties its waters into the Illinois river. The Illinois Sugar

Refining Company discharges its refuse into Dead Lake. In times of low water the color of the water in Dead Lake is very black and an odor arises from it at times. I think this is caused by the steep waters and the action of the acids that they use on the water, but that is my opinion, I don't know.

3357 CROSS-EXAMINATION, by Mr. Jeffries:

The American Distilling Company was organized in 1892. Prior to that time it was the Hamburg Distilling Company. The capacity of the Hamburg Company during 20 years was about 2,000 bushels per day. It fed, I should judge, 3,000 cattle per annum.

3358 The home office of the American Distilling Company is here in Pekin. It is an Illinois corporation. The offal and manure and drainage from that company was deposited in the same manner but hardly in the same place as that of the present company. We don't use any chemicals of any kind. The water that we use in the boilers we pump from the river and the wtaer for cooling purposes is pumped from wells drilled along the bank of the river.

3359 We feed no cattle that are not healthy and sound and give them nothing but the products of the distillery and hay, and at times some cotton seed meal. This offal from the cattle goes into the river by means of a wooden sewer. The mouth of the sewer is above the surface of the water. This offal from the cattle doesn't empty direct into the Illinois river, but empties on a piece of low ground, I should judge 100 feet from the water's edge. The sun strikes it before it gts to the water and it becomes very dry. That is true at all seasons of the year, extept during high water. We have gradually been filling up and moving this sewer further out each year. I presume that the sewer has been lengthened out a couple of hundred feet in the last ten years so that the mouth of the sewer is now about 100 feet from the river.

FRANK MILLER, examined in chief by Mr. Todd:

3361 Live in Pekin. Collected samples of water. (States method employed and places where taken, etc.)

3363 WILLIAM J. CONZELMAN, examined in chief by Judge Johns:

Am Mayor of Pekin and one of the managers of the Globe Distillery. The water supply of Pekin is obtained by means of drive wells; pumped into a tank or water tower and afterwards distributed about town. I think there are about 17 miles of pipe. About 80 per cent of the inhabitants take water from the public supply. There is a main sewer extending up First street and numerous latterals connecting therewith, constituting a sewer system of about two miles.

3364 About five per cent of the population connect with the sewers. The population is between nine and ten thousand. The remainder of the household sewage in Pekin is disposed of by means of cess-pools. The water supply of Pekin is considered very good. The rate of typhoid fever during the last three years has been normal, about the general average. About 4,500 cattle are fed yearly in the distillery of which I am manager. I would say that there would be daily about 8 gallons of urine and 4 gallons of manure from each head of cattle. The animals are fed with slop and rough feed such as hay and cotton seed hulls and about a quarter of a pound of salt to each steer. The offal from the cattle is disposed of by means of a slough or sewer into the river.

3365 It is washed out with water. The cattle are not bedded down. They are kept in sheds about eight months before they are ready for market. There are occasionally a few that become sore and are turned out into the yard. They would number about 40 or 50. Their offall accumulates in the yard and is subsequently carried off to the river bank. After this stuff is carried from the cattle shed and yard to the river, it forms an accumulation or mass which we often term an island. Usually with high water in the spring it is taken away and if not, we assist by running a boat into it or something to loosen the matter. When loosened it floats on the current of the river. A season's accumulation would aggregate a space of about 100 feet square and three or four feet deep. This condition has

been continuous at the Globe Distillery during the last three years.

3366 I have been connected with the business here since 1892 and fed about the same number of cattle from 1892 to 1900 and from 1900 to the present day, and consumed about the same amount of corn and manufactured about the same amount of whiskey. The offall from these cattle and the washings from the distillery now are emptied into the same place as they have been since January, 1900. The sewer through which this stuff flows is an open sewer with its mouth above the surface of the water at its ordinary stages. It empties directly into the river and accumulates there until there is sufficient current to carry it away. We feed nothing but healthy cows.

3367 We don't use any chemical in the manufacture of whiskey from corn. We get the water we use from drive wells.

HARRY TAYLOR, examined in chief by Judge Johns:

Reside at Pekin, am a fisherman and have been since 1895. I have fished from Lake Depew, 12 miles above Hennepin, to LaGrange dam. I have fished all the way from here to Peoria. The water is more pure and clear now above Peoria than it was before the opening of the canal.

3368 Before the opening of the canal the water above Peoria was good water. Since the opening of the canal it is good water yet, but it is better. The water in the river below Peoria before the opening of the canal was rotten. It was slimy and the slime got on our nets. At Pekin it was just the same as it was below Peoria. There was a slime to the water. Since the opening of the canal it has been more pure below Peoria. At Pekin the sliem still forms but not so bad as it was before. Since the opening of the canal the slime decreases as it goes down the river from here.

CROSS EXAMINATION by Mr. Jeffries:

3369 The current is more stronger now than it was before it was opened. I don't believe there is a mile. There is some better current throughout the year. The water is clearer

now than it was before the canal was opened, above and below Peoria. Above Peoria it is blue, like the water of Lake Michigan. It contains deleterious matter below Peoria, caused by those sugar houses and one thing and another dumps their offall into it. I don't know whether the sewage of Chicago gets in the river above Peoria.

3370 I have never seen any effect of the Chicago sewage in the water. Because I have never seen it, I don't think it hurts the water.

J. C. LOSCH, examined in chief by Mr. Todd:

I run a little boat of my own here; have done so for 12 or 15 years, the Steamer Olive A. Before the opening of the canal in summer time the river was in bad condition, the water being foul. The foulness manifested itself by smelling and in killing the fish.

3371 I have seen them between here and the locks that my steamboat wouldn't have carried them, laying on the shore, killed probably the night before, that would be about 10 or 15 tons. That was about 1889 or 1891 before I bought my big boat. The water has always been better above Peoria than it has been below. Since the opening of the canal, its effect on the waters has been to make them beteer. They seem to be purer. There don't seem to be as much smell nor look as bad. I haven't seen any dead fish to the extent I have saw before. There is some smell. It isn't so bad as that which existed before the opening of the canal. Years ago, every time we went from here to Peoria, every two or three trips, we had to blow out our boilers. We don't have to do that now. The boiler would foam and raise up with the filth and gas, between here and Peoria.

3372 As you go away from Peoria towards Grafton the water gets better. I have seen islands of manure in the Illinois river. I have struck them big enough that if I had hit them fair, they would take me down the river, with the little baot.

Those that I have reference to come from Peoria. Right here at Pekin I had clearing out the distilleries here; the

manure would be five or six feet deep and covered probably an acre that I tore out for them, they paid me $25.00 for tearing it out. That is the only place I have had to clean it out. The Peoria distilleries paid me for taking it out of the canal above Spring Lake canal, and the still house here and the Peoria parties paid me for taking it out of the canal. This manure floated down from Peoria and got into the canal and stopped it up.

CROSS EXAMINATION by Mr. Jeffries:

We see very few dead fish on the river now.

3373 The current is a little stronger. The higher the river is the stronger the current is. It is not so very much here at low water, as near as I can judge, less than half a mile or a third of a mile an hour and in high water, three or four miles an hour. I don't believe it would be much more than half a mile an hour now. The current is much swifter now here opposite Pekin than it was before. When I say the water is purer now than it was before, I judge from the appearance of it. That is the only way I have of testing the water. There is not so much smell since the opening of the canal as there there was before.

3374 (AT CHILLICOTHE, ILL.)

JERRY FOLSOM, examined in chief by Judge Johns:

Am a fisherman. Have fished off and on for about 47 or 48 years. I have fished from here clear up to Spring Valley. Before the opening of the canal the conditions of the water was poor. In the winter season when we cut holes in the ice, it would smell so bad you couldn't hardly stay around the hole and the fish would die in the nets in two or three hours' time after they were caught or confined, and they tasted of gas or tar until they wasn't fit to market.

3375 You could smell it when you was dressing them. It smelled like gas or tar. When the water got very hot there was a good deal of stuff growed in the water and it smelled bad. Since the canal was opened I haven't seen any of that growth. A little green strip comes once in a while but

the growth hasn't come here since and I haven't had any dead fish since that time and no gassy fish. The smell hasn't been nothing like it was—nothing like the gas that I have seen. The fishing is good and the fish appear to be healthy. I haven't seen any dead fish along the shores like there used to be. Before the opening of the canal there was filth of some kind settled in our nets. I couldn't tell what it was but it was filth anyway and nasty. We would find a great deal of it. We haven't had any of that since—not like that.

3376 It is 18 miles I think from here to Peoria by river. I never head of slur-gut. I never heard of such a name up here.

CROSS EXAMINATION by Mr. Jeffries:

3377 Chillicothe gets its water supply from wells and what they call the waterworks. The people here don't use the water from the Illinois river for domestic or drinking purposes. There is more current now than there used to be and the river stays higher. I have noticed the scum on the river since the opening of the canal. There is, once in a while, the green scum, but no growth over it. It looks green and at times it looks kind of greasy, but it has always done that since I have known it, at times.

3378 The dirt and filth gets on the nets to some extent, but it isn't the kind of stuff that used to gather on them before. The difference between the deposit that gathered on the nets before the canal was opened, and since, is that it was a good deal more nastier then than it is now—more slimy and more smell to it.

BRADLEY B. HAWLEY, examined in chief by Mr. Todd:

My business is steamboating and boating.

3379 Am captain of the "City of Henry." I have been steamboating and working on the Illinois river about 43 years. Before the opening of the canal the quality of the water in the

Illinois river was always better above Peoria than it was below Peoria, but in low water, it was a pretty sluggish current and the water was pretty bad—very bad water between Peoria and La Salle before the opening of the canal. In the spring we didn't notice much difference but in the hot weather or low water, and dry times, the water was what we called pretty bad, that is, it moved slowly in the river. There would be an odor at times, especially in the morning. There was a good deal of green stuff floating on top of the water. Below Peoria the opening of the canal, it was pretty bad, caused by the sewage from Peoria.

3380 The water above Peoria was a good deal better than it was below Peoria at the same time. Of course we think the sewage and polluting matter comes out of the cattle pens, but we never went up to see about it. The most we noticed is between the T., P. & O. bridge where spouts lead into the river and where sugar and still houses are located. The gas works put out a lot of bad water there. The manure that we saw in the river was in front of those spouts that run out that are supposed to be from still houses. Last summer they hired us to go in there and kick it out in the river and get the stuff away from the end of the spout.

3381 It was in the summer after the water went down. It was in June or July. There would be as much as half an acre of it. After you get down below the bridge at Peoria, say a mile below the bridge, the water begins to get thick and full of something. It is a kind of thick, dirty water.

3382 Since the opening of the canal, there is more of a current going and the water is what I should call more pure that it was before. It looks more pure and clearer to me. Below Peoria it is the same as it was before, only it isn't so bad. It doesn't look so bad to me. The water in Lake Peoria, immediately above Peoria, looks more pure to me than it was when this green scum settled on it. The water above Peoria never was very muddy, that is, after it got below this scum that used to float on it in low water. The Peoria lake water

was what you might call bad water, except when this scum was floating over the top. In my opinion, the water of Lake Peoria is better and clearer now than it was before the opening of the canal. Oftentimes we noticed a substance that looked like this stuff that passes out of the cattle pens below Peoria. It raises up in a great large piece that comes up with bubbles. It seems to come from the bottom of the river.

3383 Before the opening of the canal if you cut a hole in the ice, the water smelled bad.

CROSS EXAMINATION by Mr. Jeffries:

I live aboard the boat, but we are more at Peoria than at other points. The current in the Illinois river from Henry to Pekin is swifter than it was before the canal was opened.

3384 There never was much current in Peoria lake. It runs very slow and always did, that is excepting in high water.

3385 Peoria lake would be about 17 miles long. At one place place, Spring Bay Narrows, it is only a few feet wide. After you get below the Narrows it seems to me it is three-quarters of a mile wide.

3387 It seems to me about three-quarters of a mile wide from the Narrows to its head, that is before the opening of the canal. It would be a little wider than three-quarters of a mile all along its length excepting at the Narrows. It would be about eight or nine feet deep in the channel. Outside of the channel I wouldn't suppose there would be over four or five feet of water. It varies according to the stages of the water in the river.

3388 Q. You don't know whether the sewage gets down here or not?

A. Why, I know just the same as other folks do, that it does; that it comes here and affects the river, because there is more water than there used to be; the supposition is that it gets here.

RE-DIRECT EXAMINATION by Mr. Todd:

Our boiler used to foam below Pekin from what was sup-

posed to come out of the stillhouses and sugarhouses. Before the opening, the boilers seemed to act all right with that water above Peoria.

3389 Since the opening of the canal the water in the boilers that you take for steam seems to work better with our boat than it used to all the way along as far as we have been. The water is better now than it has been and clearer. It doesn't foam above Peoria. We haven't had any trouble between Peoria and Pekin so far as foaming in the boilers is concerned.

3390 O. F. THOMAS, examined in chief by Mr. Todd:

Have been physician and surgeon for 25 years and live at Chillicothe. For the last three years there has been no typhoid fever here except two cases two years ago. They were four blocks west of the river. The cause of those cases was not attributed to the river. The dejecta of those cases was treated with bi-chloride of mercury and run into water closets. We have no sewage system in this city, but privy vaults. We consider this a very healthy town and community. The city water supply comes from wells that are sunk along the side of the river up here at the power house.

CROSS-EXAMINATION, by Mr. Jeffries:

3391 I have been here about 48 years. These wells, in my judgment, are deeper than thirty feet. They are driven in gravel and sand. If the water comes from the river to these wells, it is filtered through the sand and gravel.

3392 The people of Chillicothe and North Chillicothe do not use the water from the river for domestic purposes. I don't consider the water from the Illinois river good and wholesome for domestic purposes. Those two cases of typhoid fever that I spoke of, I know the cause of. I had an examination of the milk supply made and it was attributed to the milk. I found typhoid germs in the milk. I had the examination made in Chicago. The milkman got the water that he used in a dairy four miles northeast of town; it was four miles from the river.

The two patients lived here in town and were in the same family and had the typhoid fever at the same time.

3393 No one else using the milk had the fever that I know of. The dairyman supplied milk to many other families in Chillicothe.

RE-DIRECT-EXAMINATION, by Mr. Todd:

The letter that the chemist sent to us said that his opinion was that the milk was the cause of the trouble.

3394 WILLIAM COLWELL, examined in chief by Mr. Todd: I came to Chillicothe in 1847. Have been in the contracting business for the last fifteen years most of the time, bridge building, etc. Helped to build the Santa Fe bridge at Chillicothe and did trestle work east of the river; then I went to Peoria the next season afterwards and built the Santa Fe road; I helped to build the upper free bridge at Peoria.

3395 Am acquainted with the Illinois river from Peoria to Beardstown. When I first went on the river in the early days back 50 years ago, the Illinois river was a very nice stream of good water, but after the towns began to grow and they pumped the Chicago river into the Michigan canal at Bridgeport, the river began to get foul and it kept on getting more so until when we built the Santa Fe bridge the river was very nearly entirely scummed over with a green coating which looked like fine vegetation. This vegetation was so thick that when we were building the bridge up here and towing stone barges, it made quite a hindrance to the towing of the barges. When the wind blew from certain directions you could smell the river pretty plain. At the upper bridge at Peoria the river was just about the same as it is here. The upper bridge was just at the foot of the Narrows.

3396 Of late years the river between Peoria and Pekin was pretty foul sometimes from the sewage and filth. At Beardstown it was pretty clear. I never could discern any filth any more in the river at Beardstown than we could up here. Since the opening of the canal I think the water is purer than it was then and less odor to it and I have never seen the river

scummed over with green vegetation since the opening of the canal. The condition of the water at Chillicothe since the opening of the canal is better than it was before I think.

3397 When I would clean out the engine and put in fresh water, before the opening of the canal, every time I would go around the engine I could smell the odor from this water and the odor was quite offensive, but since the lake water has been turned down here, I have never noticed that odor from my engine like I did before. My best judgment is that it has been 25 or 30 years back since the Illinois river was as pure here and clear as it is today; am 71 years of age.

CROSS-EXAMINATION, by Mr. Jeffries:

The city gets its water supply from drive wells, about 100 feet from the bank of the river.

3398 These wells are about 40 feet below the surface of the river I think. I think there are six 6-inch pipes. The ground or earth through which these wells are driven is sand and gravel. There are other wells used by private individuals called living wells.

3399 The people here do not use river water for domestic and drinking purposes that I know of. The farmers in the rural communities use well water. The Illinois river water has gradually grown worse for several years back and particularly so after the opening of the Illinois and Michigan canal. I couldn't tell the amount of sewage from Chicago that comes down here but the water now appears to be better than it was before the opening of the canal. I judge from using it in my engine boiler, by the difference in the smell of it, etc.

3400 I haven't noticed any odor from the river for the last year or so. The current is much stronger now than it was before the canal was opened.

J. E. DALRYMPLE, examined in chief by Judge Johns:

Live in Chillicothe and am a fisherman. Have fished for 16 years from Hennepin to Copperas Creek locks below Peoria. Four years ago there was moss or slime in the river. It was a

white colored slime. At places it was very bad and got into our nets.

3401 In our fishing above Peoria we found that some kind of slime but not so bad. I haven't been bothered with it any the last two or three years above Peoria and at htis point. Before the opening of the canal at this point we had a plant of moss growing that we called shamrock. I have seen it pretty bad. In the winter time there would be a pretty bad smell. You could smell it above the town when the river was frozen. I have seen fish die in good numbers here.

3402 There wouldn't anybody buy the mfrom me around town. You couldn't eat them yourselves. I ate one of the fish and it tasted to me just like tar. This shamrock, if you would pile it up, it would heat and then a smell would come from it. Since the opening of the Drainage canal we have had good water and lots of it. It is purer than before. I haven't noticed any odor in the last couple of years. The slime don't bother us any more. Before the opening of the canal fish wouldn't keep over night in live boxes; now our fish live very good.

3403 I am acquainted with some of the fishermen all the way from Copperas Creek dam to Hennepin. I don't know of any typhoid among them since the opening of the canal.

CROSS-EXAMINATION, by Mr. Jeffries:

I live one block from the river. We get our water supply for domestic purposes from the city. We don't carry water when we are fishing in the winter season or fall. We carry water now.

3404 When I say the water is better now, I mean it is better in every way. It is clearer, purer, and better to drink. No slime on the nets to bother the fishermen. There doesn't any slime form, particularly lately, on the nets. We used to have stuff that formed on the nets here. We ain't been bothered with it lately. Too much current for the fishing business. I haven't noticed any greasy, oily substance formed on the water for two or three years. The State Board of Health of Illinois hasn't condemned the fish in the Illinois river to my knowledge.

SAMUEL HOSSELTON, examined in chief by Judge Johns:

3405 My residence is Chillicothe and I am a fisherman. Have lived on the Illinois river in this vicinity since 1864. Before the opening of the canal the Illinois river in low water was in very bad condition. There was very little current and the water was very foul. There was a vegetation growed on the river, and being no current it would be impossible almost to get through it at places. In low water, there was an odor. There was an odor in the water under the ice in the winter. It killed nearly all the fish in this vicinity that were under the ice. Since the opening of the canal, in my opinion, the water has been purer. I see nothing more of vegetation only in pools and backwater.

3406 There is no odor in the water now that I could discover. Before the opening of the canal, the water was in pretty bad shape, very filthy, and the water wasn't fit to drink and the fish died in it. One summer here the clams all died. The river was floating full of them. Some turtles died. About the next year after the Henry dam was put in, that is when it commenced to get bad.

3409 There was a scum formed on the river and we had to skim it off. The smell in the water was fearful. The stuff would float down East river. It would be that thick you couldn't row a skiff through it and it would stink terribly. In the winter it would freeze hard and the fish would die and they were gassy and you couldn't eat them at all—just like you had fried them in tar. It got so it would be impossible for you to stand near a hole for the smell. It was just as bad as the Chicago river smelled, right under that ice, only it was kind of more gassy and I wouldn't warrant a fellow to live five minutes if he tok a drink out of it.

3410 Since the opening of the canal the water has been pretty fair. The first year the Drainage canal was opened we could seine and we never had fish to die in the live boxes. The

water is a great deal cooler. It would be so hot it would scald your feet, very near. I don't know of any typhoid fever among the fishermen since the opening of the canal.

3411 CROSS-EXAMINATION, by Mr. Jeffries:

There was no current here until after the Copperas Creek dam was put in. There is an awful current in the river now. There is some green scum on the river now in the summer time, but not like it was before.

3412 I live on a cabin boat on this side of the river.

A. C. WILKEY, examined in chief by Judge Johns:

I run a boat-yard and reside in Chillicothe. I fished on the Illinois river for about ten years from Hennepin to Beardstown. I fished below Peoria in 1897 and 1898. At that time the water was very bad. It covered our nets with slime.

3413 Before the canal was opened when the water in this vicinity was very low it was pretty bad and in the winter when it was froze up it was very bad. In the summer there was what we called shamrock and this long grass that grew on the bottom. When the river froze over before the opening of the canal the water was gassy adn the fish were so gassy that you couldn't eat them. They died under the ice.

3414 I was here the summer the clams died. It was either 1895 or 1896. They came up and floated on the top of the river. Since the opening of the canal the water has been better than it was before, as to smell. I never noticed any of that slime above Peoria, either before or after the opening. Since the opening, the shamrock plant in the water here isn't as bad as it was before. It comes out of the sloughs. I know every fisherman in this stretch of river. I have never known one of them to be sick.

3415 CROSS-EXAMINATION, by Mr. Jeffries:

I live a block from the river, have a well and cistern. I use the hydrant water entirely for drinking. There was only one time that the clams died. The fish died every winter when the river froze very solid and when it was low. The current now is considerably more than it was.

3416 Before the canal was opened there was very little current here at ordinary stages. Now there is very much more current. I see some of the scum on the river now but not very much smell.

MARTIN TRUITT, examined in chief by Judge Johns:

Live in Chillicothe. Have been a fisherman on the Illinois river for the last 25 years. Have fished between Chillicothe and Peoria and Chillicothe and Lacon. Before the opening of the canal the water of the river was pretty bad and there used to be green stuff here that you could hardly row a skiff through and in winter time if you chopped a hole in the ice you would have to get away from it on account of the rotten gas coming out. The fish would die. Since the canal has been opened it hasn't been that way. I never saw it purer in my life. The fish live better in live boxes, too, since that. The fishermen, since the opening of the canal have not had typhoid fever.

CROSS-EXAMINATION, by Mr. Jeffries:

I live in a cabin-boat. There is more curent in the river now since the canal was opened.

3418 Before the canal was opened there wasn't enough current to float the green stuff off the river. There ain't so much greasy, oily substance on the water since the opening of the canal.

CHARLES F. SCHMIDT, examined in chief by Judge Johns:

I reside in Chillicothe. Have been a fisherman for the last twelve years. I have fished from Copperas Creek lock as far as Hennepin. The water in the Illinois river below Peoria before the opening of the canal was floating about. The slime would gather on the nets so you couldn't hardly raise one into the boat.

3419 Since the opening of the canal the water below Peoria has been better. In this vicinity before the opening of the canal you couldn't keep fish alive in the live boxes very long. It wasn't as bad there as it was below Peoria. There was moss on the water.

3420 In the winter time the smell was bad. Sometimes you couldn't hardly stand it through the ice. It killed the fish every winter very near. Since the canal has been opened the water has been better in this vicinity to my knowledge, and has never killed any fish that I know of. Before the drainage was turned in the fish got so here that we couldn't eat them but since then I haven't heard anything of it. I haven't seen any green substance to speak of. I haven't heard of any fishermen having typhoid since the canal was opened.

CROSS-EXAMINATION, by Mr. Jeffries:

There is a green scum now but it grows in the backwater, unless the wind happens to blow it out.

3421 Since the opening of the canal there has been more current and more water. Before the opening of the canal the current wasn't strong only in high water. Since the opening of the canal the current has been a good deal swifter. The current used to get swifter in high water times than it gets now in high water times.

E. N. NELSON, examined in chief by Judge Johns:

Live at Chillicothe.

3422 Have been fisherman off and on for 20 years. Have fished between Lacon and Peoria. Before the opening of the canal the water in the Illinois river got very foul in low stage. In July and August the water would look green. It smelled foul and bad, especially when it was stirred up by a boat or anything. In winter when it froze up it would get a kind of gassy, tarry smell. If you cut a hole in the ice you could hardly stand over it. The fish were unmarketable at that time of the year when the river was frozen over. You could hardly stay in the house where they were cooking them and you couldn't eat them at all. They would die in the live boxes in a very short time. Since the opening of the canal the water has been very good in my estimation. I haven't noticed any smell and last winter I kept fish in live boxes for two months and a half.

3423 I haven't known of a fisherman having typhoid. I haven't known of but one case in Chillicothe in years and that wasn't a fisherman or riverman.

CROSS-EXAMINATION, by Mr. Jeffries:

3422 The river passing Chillicothe flows through Lake Peoria and on past Peoria. Lake Peoria is nothing more than a wide space in the river. There used to be a good deal of scum on the river. I haven't seen any on the river since the canal opened, only in the backwater at times.

I haven't seen any greasy, oily substance on the surface of the water. Before the canal was opened the water was very sluggish and had hardly any current at all. Since the canal is opened, the current is a good deal swifter.

3425 When I say the water is better I say that from my experience of the water, it is colder and better looking and a person can drink it in a pinch now, and they couldn't at this time of the year before. I have drank it this season and last season both, when I would be on the river.

JESSE HORN, examined in chief by Judge Johns:

Am a fisherman. Have fished off and on for 13 years between Hennepin and Peoria. Before the opening of the canal the river was stagnated water and in cold weather when it was froze up we had plenty of gas under the ice. You couldn't hardly stand it if you cut a hole in the ice and there used to be a good deal of malarial fever. I have had malarial fever pretty nearly every year. I have missed it this year so far. I don't know whether that is on account of that. The water killed lots of fish both winter and summer.

3426 There was a green substance in the water. Some called it clover and some called it shamrock. Since the opening of the canal the water has been purer and colder. We haven't had no dead fish floating around on the water. There hasn't been any smell to it and I don't know of any typhoid fever among the fishermen since the opening of the canal. I know of some, years before that.

CROSS-EXAMINATION, by Mr. Jeffries:

Every year before that as long as I have been around here there was typhoid fever. I couldn't mention just exactly how many cases. I believe there was five every year. I mean the ague or malarial fever. I don't that typhoid fever is caused from being on the river. I never knew of any fishermen having the typhoid fever in my life and I have known a good many. There has been typhoid fever in town. The scum or moss that formed on the river before the opening of the canal was some sort of vegetation.

3428 It branches out in leaves like clover. Since the opening of the canal I have seen green scum on the sloughs, not in the river. The current is now greater than it was. I have a well at home.

T. H. HARRIS, examined in chief by Judge Johns:

Am a fisherman. Have fished on the Illinois 10 years between Peoria and Lacon.

3429 Before the opening of the canal the water in the Illinois river was very bad at times. In July and August it would get kind of stagnated and of a green color. It was pretty bad on fish in winter. I have seen the fish rush up in the spring holes as if struggling for life. The mouth of most any creek would be alive with fish, that is where fresh water was coming in. There was a smell to the water in winter. Lots of fish died under the ice. Since the opening of the canal, in my opinion, the water is better than it used to be. I have never seen the fish die in the water since the canal has been turned in. I haven't seen any of this growth on the river only in the fall, and that was through the bottoms here and through

3430 Goose Pond. I haven't seen any of this growth between the banks of the river. I haven't heard of a case of typhoid among the fishermen since the opening of the canal.

CROSS-EXAMINATION, by Mr. Jeffries:

There might have been some of it but I never heard of any. Use cistern water for household purposes.

3431 Before the canal was opened there wasn't much current in the river. Since the opening of the canal there has been considerable of an increase in the current. I don't see dead fish floating in the river now. There is some difference in the channel of the water since the opening of the canal.

L. S. McCULLEY, examined in chief by Judge Johns:

Am an engineer and reside at Chillicothe. Have been an engineer on boats running on the Illinois river.

3432 Have been engineer at this Turner-Hudnett Company elevator for four years. When running boats on the Illinois river I used Illinois river water in the boilers. I have run from Copperas Creek to Henry and above. I was an engineer between those points upon boats both before and after the opening of the canal. Below Peoria, before the opening of the canal, the water foamed slightly and at times strong in the boilers. Closer to Peoria it foamed stronger than it did below. Pollution causes water in a boiler to foam. Below Peoria there was a smell to the steam that escaped from the boiler. It was a real strong odor of decayed mater. Since the opening of the canal below Peoria the water has been quite clear; it hasn't foamed any. Before the opening of the canal above Peoria the water in the boilers foamed and there was odor to the steam.

3433 Since the opening the action of the water in the boilers here has been better; no foaming and no odor excepting that that comes from natural clear water. Since the opening, the water from above Peoria is the best a little, for steaming purposes. Before the opening of the canal the water above Peoria was the better water for steaming purposes. Before the opening of the canal the water for steaming purposes taken at this point foamed in the boilers and there was an odor to the steam. The odor was stronger in summer. Since the opening the water has been better, not as much lime or scale.

3434 There was a great deal of lime and scale in the water used below Peoria. Since the opening of the canal not as much.

CROSS-EXAMINATION, by Mr. Jeffries:

There is more or less odor to all steam. It depends upon the water. At times the water in my boiler here at the elevator foamed very badly prior to the opening of the canal. The foam comes from decayed matter. The substance in the water which caused the foam was not altogether decayed vegetable matter.

3435 The cause of the foaming was the pollution in the water and the water at that time was stagnant both above and below Peoria.

(AT LACON, ILL.)

WILLIAM MANGLE, examined in chief by Judge Johns:

Am fisherman. Have been a fisherman on the Illinois about 18 or 20 years. Fish between Henry and Chillicothe all the time.

3436 Before the opening of the canal the river at this point was pretty low. It had a kind of moss or green stuff floating in it in low water. It would be probably a foot deep along the shore. No smell in summer to amount to anything. The water was pretty bad under the ice at low stage. It was gassy. When you cut a hole in the ice a kind of gas or tar smell came out. The fish would taste just like it smelled. A good many died under the ice. Fish didn't live long in hot weather in live boxes. Since the opening of the canal there hasn't been much of the green plant in the water. No smell under the ice and the water is better a good deal, and the fish live better. We drink the water in cold weather. Fishermen in this vicinity haven't had typhoid fever that I know of since the opening of the canal.

CORSS-EXAMINATION, by Mr. Jeffries:

The population of Lacon is 1200. They get their water from wells.

3438 These wells are not over 40 feet deep, driven through gravel and sand. There are a lot of living wells in town.

People don't use water from the river for domestic and drinking purposes. There is a scum on the water at present. It is a kind of thin scum instead of them seeds, a kind of an oily substance. Before the canal was opened there was a very little current in the river. The current is now much stronger. There is quite a good current all the time. There is a good current in the river now from Henry to Chillicothe. If a steamboat stirs the water up now I believe you can smell a kind of smell to it, a kind of a dead smell.

3440 JOHN BAUMISTER, examined in chief by Judge Johns:

Have been fisherman on the Illinois river since 1867. Fished from above Hennepin down the river as far as Pearl. We have a little tug of our own. Before they turned that canal in, the water used to foam and we had to blow her out every two days and last year we never had to blow her out once, so the water must be purer. What they called duck seed growed awful thick some places. You couldn't hardly seine through it. There has been very little of that lately. When it was frozen over a short time the water became gassy and smelled and the fish tasted tarry so we couldn't eat them. Since the opening of the canal I never noticed any odor under the ice. I don't know of any fishermen having typhoid fever since the opening of the canal.

CROSS-EXAMINATION, by Mr. Jeffries:

I live in the first house up here on the bank of the river.

3442 Have a living well. The green scum that formed on the river before the opening of the canal was duck seed. The scum that forms now would be about the same, but not near as much of it.

3443 Before the canal was opened there was a very little current in the river. No current to speak of at all. Now there is a good current at all times of the year from Hennepin to Peoria.

WILL REED, examined in chief by Judge Johns:

Am fisherman. Have also fired on steamboats. Have been occupied as a fireman on the Illinois river pretty much every

summer more or less. I have traveled from Peoria to La Salle and from Peoria to St. Louis on the Cherokee. I made a trip or two on the Bald Eagle. I noticed a difference in the quality of the water for steam purposes above and below Peoria.

3444 Q. What was the difference before the opening of the Drainage canal?

A. Well, sir, from the time you leave Peoria; of course after you get past them still houses down there it is all right. For a ways after you hit them still houses it is bad; that is, it would foam and it was foam up here; it was a kind of a scum raised up in your boiler and made it foam. We would notice that foaming in the boiler until we got down pretty near to Copperas Creek. From Copperas Creek down to the mouth of the river the water was certainly better for steaming purposes. We was bothered more was sand in the boilers. The water was mud run; more sandy the water was. At times there was foaming in the boiler below Copperas Creek dam.

Q. How was the water below LaGrange dam as compared with the water above Copperas Creek dam?

A. I think it was better above; that is, the quality of the water.

Q. How was the water below Kampsville dam as compared with the water above Copperas Creek?

A. Well, I think it was better; couldn't see much difference in it. From Kampsville dam down the river the water foamed in the boilers more or less; after we got down about Alton there and got down below there; after we got into the Mississippi. In the Illinois river below Kampsville and down to Grafton the water foamed more or less; there wasn't no big amount of foaming or anything of the kind. Above Peoria before the opening of canal the water foamed in the boilers.

3445 The better water for steaming purposes as compared to the water in Peoria Lake, was the water here at Lacon.

Before the opening of the canal the water at this point (Lacon) I have seen it pretty bad at times. It had scum and one thing and another. There was a smell in the water. The water under the ice in winter was pretty foul. It killed lots of fish along the river between here and Henry. The fish were not fit to be cooked. Above Peoria, since opening of canal the water has been first rate for steam purposes. I haven't had no foaming; every time I was firing I have seen none of it.

3446 Since the opening of the canal I didn't find any odor or smell when the river was frozen over. I haven't seen any dead fish in the water. Before the opening of the canal the fish did not live very good in live boxes; now I could hold them four and five days. There hasn't been any considerable amount of this green plant in the river. The fishermen upon the Illinois river in this vicinity do not have typhoid fever that I know of.

CROSS-EXAMINATION, by Mr. Jeffries:

Before the canal was opened there was very little current in the river here at Lacon. Since the canal was opened

3447 we have a good fair current. I haven't noticed any green, oily or greasy scum on the river since the canal was opened.

Q. You know that the oily green scum does form on the river since the opening of the canal, right here where this boat stands?

A. There is some there, yes, sir. It is a kind of a scum, it isn't very bad at that. I use cistern water at home.

3448 FRED MAWBEY, examined in chief by Judge Johns:

Reside at Lacon. Have fished upon Illinois river 25 years or more. I fished from LaSalle as far as below Naples. I fished at Havana before opening of canal. The conditions were bad; there was a white slime in the water that collected on the nets. The nets would fill up so that two men could hardly lift them. The condition of the Illinois river in this neighborhood (Lacon) before the opening of the canal was bad. Through the summer season it would be green in fact from top to bottom and in the winter season, take it above Henry dam, it would take it about

8 or 10 days to kill every fish in it. There was a smell in the water in the summer and in the winter the smell was so bad you would have to cover your face when you went across the bridge at Henry dam.

3449 The fish tasted gassy; you couldn't eat them at all, nor you couldn't stay in the house where they were cooked. Since the opening of the canal the condition of the river in this vicinity has been good. There has been no smell or odor in the river here in the winter or summer that I know of. The fishermen on the Illinois river in this vicinity since the opening of the canal, do not have typhoid fever that I know of.

CROSS-EXAMINATION, by Mr. Jeffries:

I couldn't say whether they had typhoid fever before the canal was opened. There was lots of ague though. I never seen anybody have any typhoid fever along the river neither before nor after the opening of the canal. I have seen them have it in town—in Lacon. Not very much of it. There was a man died with it here day before yesterday. That is the only case I know of since the opening of the canal. I don't remember of any before the canal was opened.

3450 I live in a house boat up on the bank of the river. Before the opening of the canal in low water there wasn't any current to speak of. The current now is good at all times. This green scum that I spoke of on the river prior to the opening of the canal was in the river; the river was just about the same as dead water; there was no current. If it was not for the steamboats running in it, I don't believe you could live on it; they stirred the water up. I have seen the water you could take a 16 foot oar and stir it up, put it down and it would come up green. Of course seeds would form on it at times; I have seen them at times from Henry to Lacon 2 feet deep. Since the opening of the canal there is not very much vegetation. There is not much scum unless you go into the slough. When I say the water is better since the opening of the canal than it was before I judge from its appearance and the clearness of it—from its looks.

3451 HENRY STOEHRS, examined in chief by Judge Johns:

Reside at Lacon. Am engineer at the woolen mills. Have held that position for 20 years. For 12 years have obtained water from the Illinois river for my boilers. Before opening of canal water used to be very slimy, scummy, muddy. It didn't act very good in the boilers. It foamed the boilers and we would have to blow them off pretty often. There was a smell to the steam when we blew them off.

3452 The stuff that came out when we blew them off was a kind of a muddy scum, with an awful smell to it. Since the opening of the canal it is better. I don't find that scum in them at all and haven't. The water foams very little in the boilers. There is no odor to the steam now. The water that comes off when I blow off the boilers now is in very good order; there is very little mud and very little scale.

CROSS-EXAMINATION, by Mr. Jeffries:

The people living in Lacon don't use the water from the Illinois river for domestic and drinking purposes. Before

3453 the opening of the canal the water in the river was awful. No current. Since the canal was opened it is better. Seems to be a good current. The water foamed in the boilers in summer and winter before the canal was opened. Boiler house is 1200 feet from the river. There was no occasion for driving a well to get water for the boilers. I don't think the water was so bad that I couldn't use it for that purpose. The green scum that formed on the river before the canal was opened was of a vegetable character. I don't drink river water as long as we have got well water.

3454 I have heard and read that the water in the Illinois river was pretty good for drinking and domestic purposes during the last two years. I have heard it condemned also. I don't know of anybody that uses it.

JOHN FAY, examined in chief by Judge Johns:

Reside at Lacon. Have been fisherman on and off on Illinois river for 15 years. Fished at Chillicothe and Peoria and down as far as LaGrange. It has been about 10 years I guess

when I fished below Peoria. Before opening of canal the water at this point (Lacon) was pretty bad, take it in the winter time. It kind of smelled after you cut open the ice; kind of a gassy, tarry smell. It killed a good many fish in the river; when it didn't kill them they tasted tarry, kind of tarry.

3455 They wouldn't smell but they tasted tarry. Since the opening of the canal the condition of the river has been better. The fish have not died here in the water since. It hasn't had any smell. There hasn't been much, if any, of that green growth in the water. There was a good many duck seed on the river before the drainage was opened. Since the opening of the canal the fishermen in this vicinity had not had typhoid fever.

CROSS-EXAMINATION, by Mr. Jeffries:

I don't know as any fishermen had typhoid before the canal was opened. There is a good deal of difference in the current of the river now—more current now than there was then. It was pretty dead water then. There is a good current here now. There is a little scum yet. There is more oil to it now. There is a good current in the river over the whole distance I have been fishing lately.

WILLIAM V. McKINLEY, examined in chief by Judge Johns:

Reside at Havana. Have been an engineer upon boats on the Illinois river. Have been licensed engineer since

3457 1884. Ran engines on the river before that for five or six years. Have been in the employment of the Illinois State Fish Commission since 1894; not continually; I was off two years, last year and the year before. During my employment by the fish commission I have traveled the whole length of the Illinois river as far as navigable with our boats and have been on the bayous, tributaries and lakes tributary to the Illinois river.

3458 I know the general condition of the river at different times of the year and all along the river. The Illinois river does not scour or clean itself in any of its stretches or reaches, to any extent—not to amount to anything. (Objected

to by Mr. Jeffries for reason that witness has not qualified himself.) The river does not change its channels in any of its stretches. (Witness temporarily withdrawn.)

J. W. POTTS, examined in chief by Judge Johns:

Reside at Lacon. Have been a physician in Lacon and vicinity for 11 years or more. My practice has extended south to Crow Creek; that's about six miles, and north probably 3 or 4 miles.

3459 Lacon receives its water supply from wells probably 1000 feet from the river. I was on city council when they lowered the well. My recollection is that the bottom of the well from the top is about 39 feet. It is open for 20 odd feet and then driven from there down; pipes. Three-fourths of the population get their supply of water from this public supply. There is no sewerage system in Lacon. The domestic sewage is dumped in cess-pools, top drainage, of course. Most of them are just allowed to drain. The modern cess-pools of course are cleaned out, but they are not numerous. This drainage is absorbed mostly, I should judge.

3460 I do not know of any typhoid fever in this community within the last three years, neither among the people along the river nor back from the river.

CROSS-EXAMINATION, by Mr. Jeffries:

Three-fourths of the people use the water from the public water supply. The remaining people procure their water from some public wells here, and then there are cisterns. This water that is used from these wells, is filtered through the sand and gravel. That is the theory on which they were built. None of the people of Lacon and vicinity use the water of the Illinois river for domestic purposes to my knowledge. I wouldn't recommend the water of the Illinois river for drinking purposes since the opening of the cnal nor at any other time.

3461 S. S. EVERETT, examined in chief by Judge Johns:

Have lived in Lacon seven years and a half. Am physician and surgeon. Am a graduate of the regular school. Have practiced in this vicinity for ten years and a half. Practiced

the remaining years in Sparland, across the river, a community of 450. They have no public water supply—they have largely well water over there. We have a public supply here (Lacon.) The water is taken from the deep wells down on the bank of the river. We have no sewerage system. Natural drainage is ideal —the lay of the land, and the sub-soil is sand and gravel and there is perfect drainage almost to the river. There is no strata of sub-soil to hold the water and prevent it going down towards and draining back toward the river. The natural subterranean drainage is towards the river. Household sewage is dis-

3462 posed of by cess-pools and privy vaults. I have had only 4 cases of typhoid fever in the last three years. They were in town and I think imported cases. Dejecta of patients was disinfected and buried as a rule. We have a little malaria along the river all the way here; it is not severe; the types of malaria here are not severe; they are easily treated; it is getting less and less as my judgment serves me.

3463 CROSS-EXAMINATION, by Mr. Jeffries:

There was a little typhoid fever before opening of canal. About the same as now. I don't notice any difference about that. The malarial fever has been growing less and of a milder form particularly the last two or three years. And from what the older physicians have told me it is of a much milder form now than formerly. None of the people of Lacon or Sparland use river water for domestic purposes. Would not recommend river water for domestic purposes since opening of canal—never would. These wells here in Lacon obtain their supply by filtration through sand and gravel.

(AT HENRY, ILL., JULY 24, 1903.)

J. A. McCUNE, examined in chief by Mr. Todd:

3464 Live at Henry. Took water for Sanitary District and University of Illinois in 1899 and 1900 at the dam at the north end of the lock. (States method of taking samples, etc.)

3466 CLYDE BAUTER, examined in chief by Judge Johns:

Live here in Henry. Have been fishing here for last nine

years. I fished about three miles below Copperas Creek and clear to Spring Valley. Below Copperas Creek before opening of canal the water was low; it was in the fall of the
3467 year when my brother and I were down there. The water seemed to be all right then. I couldn't see nothing wrong with it then; it was a little scummy along the banks. There was slime in the nets in the fall and winter time. They don't slime to amount to anything now. At this place before the opening of the canal the nets took the slime up a great deal and the water used to be green and scummy like. I don't think it was as pure as it is now by no means. In the winter time in low water when the river froze the water would get gassy, tarry and make the fish taste so people couldn't eat then. There was no market for them; fish couldn't stay in the back water lakes in low water before the drainage was in. Since the drainage canal was opened the first year the water wasn't as good as it
3468 is now; now the fish lives good and everything; we wouldn't ask for any better water at all, and the boilers on the boats don't foam or nothing. Four years ago we couldn't keep steam in the boiler for foaming water; she would foam over. I have run a boat operated by steam on the Illinois river five years this July 1st. The water foamed in the boilers
3469 prior to opening of canal below Peoria, in the summer time. First year after canal was opened she foamed a little bit, but she don't foam any more. Since the opening of the canal the water from Peoria to Spring Valley is all right for the boilers; no complaint at all; for the last two years there ain't been no foaming done in the boilers at all. I am acquainted with nearly all of the fishermen between here and Copperas Creek. I don't think there is anybody that I know of amongst the fishermen that had the typhoid fever in the last three years. I know, by golly, I ain't had the chills for a long while.

CROSS EXAMINATION by Mr. Jeffries:

3470 I get my water for domestic purposes out of two cisterns. The people of Henry got their water supply out of wells

and cisterns until they got their water system here last fall. Before opening of canal people did not use Illinois river water for domestic purposes.

3471 The water in the Illinois river below Peoria the first year after the opening of the canal didn't look as good as it does now nor as good as it did before the canal was opened. The current from below Peoria to the Henry dam before the canal was opened was pretty swift. Since the canal was opened it carries a pretty good stream, about four miles an hour. The green scum that formed on the water before the opening of the canal was of a vegetable character as near as a fellow could get at it. There is some scum yet on the

3472 banks, but not in the middle of the river. In the winter time and in the fall slime forms on the nets yet, but it ain't the same stuff. It is a kind of rotten stuff; it don't hang on like the other did; the other stuff was a kind of a glue.

B. F. FORREST, examined in chief by Judge Johns:

Reside in Henry. Have been a physician for 20 years and practiced in Henry and vicinity about 13 years. My practice extends in a general way as far north as Hennepin and as far south as Lacon. I was mayor of the city from 1892 to 1894 and 1898 to 1900. We have no system of public sewers. As

3473 a rule the household sewage is thrown out. Some people haul it away in barrels but the most of it is thrown on the top of the ground in back yards and alleys, a large portion of it, and privies. There are no cess-pools here. The population is about 1,700. There are two cases of typhoid here at present. One of the patients has been away from home, visiting in Indiana and was taken down with this malady at once after returning, and has had it for three weeks. I don't

3474 know what to attribute the other case to. I enquired particularly as to any cause of infection and learned that they have been using cistern water only. Since the opening of the canal there has been no deaths from typhoid. The dejecta of the two patients is disinfected with carbolic acid and lime and emptied into the vault. I have fished a good deal on

the river with pole and line and also backed a seining outfit knowing what they were doing. At this point before the opening of the canal in times of high water the Illinois river was in good condition—that is the condition of the water was fairly good. In conditions of low water the water was very bad, polluted. After the river would become frozen over, there was a break in the column of ice at the dam; at times the gases that would arise from that break in the dam where it didn't freeze over would become very bad; at times so much so that it was offensive. The effect was to kill the fish. The fish were tainted and unfit for food.

3475 Since the opening of the canal the water apparently has been better; there has been an absence of this stench and I haven't noticed it as much, not near as much. As to the fish I have heard no complaint. I have known the fishermen have taken them all this season and used them for food. It is 30 miles from here to LaSalle and 33 to Peoria.

CROSS EXAMINATION by Mr. Jeffries:

The water system has only been in operation three months. Before that the water was taken from cisterns and wells. The water from the river was not used except in ice. The ice is cut from the river or the little ponds supplied from the river. There were cases of typhoid here before the canal was opened. There never has been an epidemic. There hasn't been 20 cases of typhoid fever since I have been here. I wouldn't recommend the water of the Illinois river for domestic purposes.

3476 There is more current in the river now; at times before the drainage canal was put in there was no current or almost none. When the water was low it was ordinarily worse; very low, it became stagnant.

WILL SIEWERS, examined in chief by Judge Johns:

Live at Henry; am grocery clerk. (Took samples of water. States method employed, etc.)

3478 ELMER MELICK, examined in chief by Judge Johns:

Am lock tender at the Henry lock. Held that position since October 1, 1900. Before that I was three seasons with

Capt. York on the steamer Peoria; 5 or 6 years I was with a grocery store at Henry and I was east about 1 year. The steamer ran from Henry to Peoria and return. The distance from Henry lock to Copperas Creek dam I think is 65 miles. Henry is a State dam. Since I have been attending the locks the water of the Illinois river has been lots better than it was before. Before it used to be a bad odor arise from it and since I went to work over there I haven't noticed this odor. The river at this point tday is higher than the average. The lower guage is 8.9; the upper guage that gives the water on the dam is 2.4. The upper gauge shows that there are two feet and four-tenths of water going over the dam. The flash boards were taken off this dam before I came here.

3480 Since I have been here the extreme low water mark on the lower guage to the best of my recollection was I think about six feet.

CROSS-EXAMINATION, by Mr. Jeffries:

The dam across the river is 540 feet long, I think. The water is now 2.4 deep on top of the dam. In years gone by we ought to have about 1.2 on the dam. That is before the canal was opened. The current now is prettty swift. The fishermen are all kicking about it, is all I know. They say they can't seine. Occasionally see a green, oily substance forming in the lock now; very little though.

3481 WILLIAM McKINLEY, direct examination continued by Judge Johns:

Before opening of canal, the water in the Illinois river in dead low water, from Kampsville to the mouth, was very bad. It was stagnant; weeds grew in it. Since the opening of canal there is more water and running water, and there isn't any moss or any vegetation of that kind. It has been all right for steaming purposes. Before opening of the canal the water between Kampsville and La Grange dams was about the same as it was below; there wasn't so much vegetation on account of the dam held the water up; made the water deeper here. I heard them say at Meredosia that the Kampsville dam raised the water four

inches at the lock. Before opening of canal the river between La Grange and Copperas Creek dams was a kind of a pond like; not much current; stagnant. We would have to clean the boilers every 8 days, we calculated on. After the opening of the
3482 canal the river between La Grange and Kampsville dam was improved to what it was before. For steaming purposes it was about the same as river water; you couldn't notice much difference; we had to clean the boilers every so often any way. The water was cleaner than it was before; at least we don't get as much out of the boilers. The water between La Grange and Kampsville dam since the opening of the canal is about the same as the water below Kampsville dam. It is 83 miles from La Grange. I don't know how far the influence of La Grange dam is felt. But it is felt at Havana, about six inches there.

3483 Before opening of canal the water between Copperas Creek and La Grange was low and there wasn't much current; it was stagnant the same as it was below. After the opening of the canal it was improved the same as it was below. When we cleaned out the boilers we had more real mud than we did before the opening of the canal; as to lime and scale I don't think it made any difference. After the opening of the canal the water between Copperas Creek and La Grange was all right for steaming purposes. The farther up the river you got I think the water was worse until you get to Peoria. From Pekin to Copperas creek dam before opening of canal the water was pretty rank, pretty bad. From Pekin to Peoria it kept getting worse that is in low water. There was more sediment in the
3484 water and it was more difficult to get an injector to work between Pekin and Peoria than it was below there. After opening of canal water was improved between Copperas creek dam and Pekin. There was more water. It was all right for steaming purposes. If you let the boilers get dirty or run them over, they would prime, it didn't make any difference where it was. After opening of canal water between Pekin and Peoria was and is still bad—it has improved some. We haven't had any

dead water. The water from Pekin to Copperas creek dam is not as good as from Copperas creek dam to La Grange. Prior to opening of canal water from Peoria to Chillicothe was all right, good. It is still good. You couldn't tell much difference in it as compared to its condition before opening of canal. Before opening of canal the water between Chillicothe and Henry dam was all right, but there wasn't much current; it was kind of a stagnant place; every now and then there would be a green scum on it in low water or warm weather.

3485 Before opening of canal water from Henry to Chillicothe was about the same as the water from Chillicothe to Peoria. After the opening it was about the same. I couldn't notice any difference for steaming purposes. Before opening of canal the water from Henry to La Salle was kind of stagnant, slow current, same as it was between here and Peoria. Since opening of canal it has improved, there is more water.

3486 In cleaning boilers at Peoria after coming up the river there would be no smell in the water to speak of.

CROSS-EXAMINATION, by Mr. Jeffries:

Since opening of the canal the current has increased and there is more water. At times before canal was opened there was scarcely no current at all. In places not any; in wide water there was scarcely any. The odor I spoke of as coming

3487 from the water before the canal was opened was mostly from decayed vegetation. There is more or less odor to all steam, after the boilers begin to get dirty. I haven't seen any green scum since the canal was opened. If you run the boilers too long the water will foam; you can notice it when the whistle blows. When the waters foams it is because the boilers get very dirty. As far as for boiler purposes is concerned

3488 you can't notice much difference since the canal was opened. the water looks better and has a better appearance all the time so far as that is concerned. I don't know what is in it. I don't drink the water because I can get better water. I have drank it and do yet in the spring and when I am out hunting and can't get any better.

A. G. HUMPHREY, examined in chief by Judge Johns:

Live at Henry and am in the grain business. Prior to
3489 opening of canal water in Illinois river at this point was very bad. It had a greasy scum on the surface of it and it smelled like coal tar, and in low water that was very bad. In low water in summer time I have seen it covered with a vegetable growth. In winter after the river had been frozen over for a while we could notice a very strong odor of gas, or tarry; the wind would blow it towards town. Since the opening of the canal I have not noticed anything of the kind; the water seems to be a good deal purer; and not that green stuff on the surface. I haven't noticed any odor in the winter.

CROSS-EXAMINATION, by Mr. Jeffries:

There is more current in low water now than there was before. I think there is a great deal more in low water.
3490 There were two kinds of scum on the river; one was a vegetable matter we called duck seed: the other was a greasy substance that would be on the surface of the water when it was calm. I never noticed any of that greasy substance on the water since canal was opened. I don't drink the river water. It wouldn't be considered good water for domestic purposes.

W. T. LAW, examined in chief by Judge Johns:

Live at Henry and am a banker. Have resided in Henry 44 years. Before opening of canal, water in Illinois river I did not consider was in as good condition as it is today; the water wasn't very good; there was a smell about it in the summer time in the evening and I don't notice that much now. There was usually a green scum on the water here in the summer before the opening of the canal. From its general appearance today I conclude that the water is better than before the opening of the canal.

CROSS-EXAMINATION, by Mr. Jeffries:

The people in Henry just put in a water system this season. Prior to that water plant they used water from driven wells and open wells and cisterns. They don't use water from the river to any extent. There is more current in the river and the water

seems to be clearer. I have made no examination of it.

3492 FRED BAUTER, examined in chief by Judge Johns:

Live at Henry. Have been fisherman on the Illinois river between 9 and 10 years. Run a steam tug or boat in my fishing on the river. Before opening of canal below Peoria to Copperas Creek take it along in the winter time and when the water began to get cold, it was so dirty and slimy that you couldn't set the nets. The slime stuck on the nets in big chunks; it was a white slimy stuff, sticky. Fish would not live in the live nets. Water foamed in boilers in hot weather. Put coal oil in boilers to keep foam down. Above Peoria the water was not so bad. You could fish any time of the year up here and never get any slime. Above Peoria we never had any trouble with the boilers at all. Before opening of canal the water above Peoria was awful green; especially along at Peoria, and a green matter would collect; there was no current to let it pass. At Henry the condition was about the same as it was below. Above Peoria and up to this point in the winter time when it used to freeze over the water would get bad and kill the fish off, and the water and fish both would smell tarry and taste tarry. Since the opening of the canal the

3494 conditions above Peoria and up to Henry has been good; the water is more pure; keeps cooler, fish keep a good deal better and there is no time in the water that you can't drink it. I never notice any smell. Am pretty well acquainted with the fishermen. Since opening of the canal I have not known of any typhoid fever among them.

CROSS-EXAMINATION, by Mr. Jeffries:

Before opening of canal there was scarcely any current in the river. Now I judge it was about two miles and a half an hour. I think this scum that used to form was filth; that is how it looked to me; there was a green scum from the duck seed but this wasn't. I have not noticed any of that filth now; may be once in a while you will see a little piece. I don't know where it has gone to. I think it is all stopped up. It must still be in the water.

3495 H. HALL, examined in chief by Judge Johns:

Reside at Henry and am an iceman. Put up ice at this point 9 seasons. Before opening of canal ice had a good many sediments in it; after we cut the ice out of the lake there would be a scum over the water where we would take it out. There would be a smell to the water after it was froze up a while. It would kill the fish. Fish would freeze up in the ice and had to cut them out in summer. After canal was opened in January, 1900, we took a chunk of ice out of the lake and one that we took out a year before that and boiled them and found that the ice that we took out of the lake was better ice than the ice that we had in the house. This ice is taken out of the river; you might call it the river. Since the canal was opened we haven't

3496 noticed much sediment. Noticed no odor last winter where we took the ice out but there was some odor at the dam but not quite as bad as it was the year before. Haven't found any fish in the ice since the opening of the canal.

CROSS-EXAMINATION, by Mr. Jeffries:

The current is much swifter now than it was before the canal was opened; you can't do any fishing here with a seine at all.

The smell at the dam last winter was not near as bad as it was before. We have a pretty good stage of water.

3497 I don't know what has become of the green scum unless the current carries it away.

MR. JEFFRIES: I move to strike out all the testimony of all the witnesses taken on the Illinois river dating from Monday, July 13th to Friday, July 24th, who have testified as to the character of the water before and since the opening of the canal for the reason that the said witnesses did not properly qualify themselves as being competent to express an opinion or give their judgment on the subject; and for the further reason that water may be apparently clear and at the same time be filled with germs of disease, and that testimony of the character in question is incompetent and immaterial and irrelevant. Move to strike out all testimony of witnesses and physicians as to

the typhoid fever cases up the river for the reason that the evidence shows that the Illinois river water has not been used for drinking or domestic purposes to any extent and therefore could not be the source or cause of the increased typhoid death rate in St. Louis; and move to strike all the evidence of witnesses testifying to the water foaming in the boilers for the reason that such fact does not prove or disprove that the water is in a better condition from a sanitary standpoint since the opening of the canal than it was prior thereto, and for the further reason that it is incompetent and irrelevant; and I move to strike out the testimony of all witnesses to the deposit of material in the Illinois river at Peoria and Pekin and other places for the reason that such fact is no justification for the right of the Sanitary District and the city of Chicago to discharge the sewage of Chicago into the drainage canal and thence into the Illinois river and for the reason that all the testimony so taken between said dates and places is incompetent, irrelevant and immaterial.

(NATIONAL HOTEL, PEORIA, ILL., AUG. 14, 1903.)

H. E. BEASLEY, examined in chief by Judge Johns:

3499 Am city engineer of Peoria. Have been since Oct. 15, 1900. Water supply of Peoria is owned by a private corporation, the Peoria Water Company. Until about 1888 the waterworks system was owned by the City of Peoria. Water is obtained from a water bearing strata of gravel, located about 3 miles northeast of the court house, or the central portion of the city and about 300 yards from the Illinois river at ordinary stage of water. The water is taken from a well fifty feet deep. I cannot say positively but in my opinion this water comes from the opposite direction to that of the Illinois river. There is an auxiliary well located some 330 feet east of the plant and connected with the main pumping plant by a vitrified pipe some 30 inches in diameter. This auxiliary well is not more than

3500 25 feet from the Illinois river at ordinary stage. These

wells are located in what might be called the bottom lands and in the vicinity of the well are not subject to overflow and periods of high water in the Illinois river. The bottom of these wells extends below the ordinary level of the bottom of the Illinois river. All distilleries, glucose works, in fact all large corporations located along the river have their own private water supply. In all cases these wells are sunk to this water-bearing gravel, and are located within 100 to 300 yards of the water of the Illinois river at ordinary stage. The water company does not furnish the city with information regarding the number of gallons of water pumped der diem but I would judge it to be in the neighborhood of 5 or 6 million gallons every 24 hours. The census of 1900 gives the population of Peoria as 58,600. There has been an increase since and a conservative estimate of the present population would be about 70,000 to 73,000.

3501 After being used for domestic and manufacturing purposes the water from the public water supply in a large majority of cases is turned into the public sewers of the city. We have official records in the office of 2,500 connections with the public sewer. This record is not complete and I would judge that there would be in the neighborhood of 3,000. These connections are from all buildings, residences, hotels, or any other public building. There are three hospitals in Peoria and they are connected with the public water supply and discharge their sewage into the public sewers. Where corporations and manufacturers have their private water supply their sewage is discharged into their private drains leading into the Illinois river. Peoria is located on the west bank of the Illinois

3502 river and extends about 5 miles along the bank of the river. Kickapoo creek is below Peoria and empties into the Illinois river very close to the south-western corporate limits of the city. The creek is about 18 miles in length and of an average width in low water not more than ten to fifteen feet in places. In high water it overflows and extends over the lowlands to a width of 300 feet.

3503 Averyville is a village north of Peoria lying along the

banks of the Illinois river. The city of Peoria is located on the bank of the Illinois river, the ground rising from the river bed to the bluffs and extending back from the brow of the bluff a distance of approximately a mile and a half. This bluff is about 200 feet above the river bed in some portions and from three quarters to about a mile and a half from what might be termed the foot of the bluff. The surface drainage of the streets, alleys and public areaways of Peoria flow into the public sewers, wherever they are located. In places where there are not sewers it empties into the Illinois river, through conduits or ditches. The street sweepings are dumped into what is known as the levee on the river front, the larger portion, however, being distributed on lots which are lying low, throughout the city. About 40 per cent of the city of Peoria is

3504 sewered. About one-fourth or one-third of the population discharge their sewage into the city sewers. The remaining 66 per cent is discharged into vaults. Paper marked "City of Peoria; Sewer Map, January, 1898" represents the sewers of Peoria; the entire system of the city of Peoria at that date to which I have added the Persimmon street and Chestnut street sewer systems which have been constructed within the past year. This represents Peoria before annexation of what were formerly known as North Peoria and South Peoria.

3505 The brick sewers of Peoria are about 21 miles in length; the pipe sewers about 58 miles in length. Map marked Defendant's Exhibit No. 1. Objected to by Mr. Jeffries.

3506 (It is agreed that every possible objection pertinent to any question to any witness may be considered as having been made by complainant to defendant's testimony, with respect to the character of the deposits or discharges into the Illinois river from its mouth to Lockport dam, and this objection shall go either as to the form of the question or substance of the question. F. S. B., Commissioner.)

CROSS EXAMINATION by Mr. Jeffries:

3507 The people of Peoria do not use the water of the Illinois

river unless it be those that live in shacks or houseboats on the banks of the river. The mains of the waterworks do not extend all over Peoria. Where the mains do not extend the people have wells or cisterns.

3508 The water from the well of the water company is taken from the lower side of an impervious strata of clay or shale. The private wells throughout the city are from above this point.

3509 PETER CASEY, examined in chief by Mr. Todd:

Live at Peoria. From August, 1895, to June, 1901, I was manager of the Whiskey Trust. Since that time have been manager of the Corning Distilling Company. At the time I had the management of the Whiskey Trust there were four active distilleries located in Peoria, the management of which I had. From 1895 to 1900, we fed from 12,000 to 20,000 cattle. The most we ever had was in 1896 when we fed 20,000. In 1897 we fed 15,000; in 1898, 12,000 or 14,000; in 1899, 12,000; in 1900, 8,000 or 10,000; in 1901, 10,000; in 1902, 8,000.

3510 During the years the distilleries were known as Trust Distilleries, we ran a capacity of between 17,000 and 18,000 barrels a day. The corn is first ground into meal and put into large cookers; the heat is drawn out by a vacuum and malt is added to convert the starch into sugar. It is then fermented and separated over a beer still, which separates the whiskey from the slop and the slop is then pumped to the cattle and fed to them. This slop is principally composed of protein and fat. It has a certain amount of moisture and with other minerals in there, such as ashes, etc. The average protein is 33 per cent and the fat about 11 per cent and the other 66 per cent is composed of the other minerals that I spoke of. The cattle are kept in sheds built in sections. The slop is supplied to them and the offall is pushed out not less than twice a day into a sewer which is directly behind each steer.

3511 This is pushed out into the main sewer that runs through the middle of the cattle barns and water is used to flush that into the river. Hay, cotton seed meal and cotton seed

hulls are also fed. The rule is to feed a bushel of slop to every steer but that has been modified to about three-quarters of a bushel. There are about 31 gallons of slop to a bushel. From 7 to 10, and as high as 15 pounds of hay is fed to a steer daily and from a pound and a half to two pounds of hulls. Salt is given to them frequently.

3512 I suppose some of it goes through and is wasted. 10 or 15 barrels are used every week in the feeding of 10,000 head of cattle. The urine and manure from the cattle go into the river. Some of these sheds are directly on the bank of the river and I think the farthest is about 700 feet. Sometimes the manure accumulates on the bank of the river.

3513 These accumulations have been pretty extensive. This last high water took them all away again. In the absence of high water they just lay there and disintegrate. They have been dislodged by steamboats and floated down the river in large islands. These islands of manure were so large that they could not pass between the piers of the Pekin bridge. The condition of the river before the opening of the drainage canal below Peoria was very bad. It smelled so bad sometimes that we could hardly stand it along there. The water seemed to be perfectly stagnant and there was no life to it. I have noticed a foam on it. I think it was the offal from the cattle barns that caused that condition in my opinion. The water above where it received the offal of the cattle barns was a great deal better but nothing like it is now. Since the opening of the canal the water both above and below this point has been much improved in every way, especially for mechanical purposes.

3514 I haven't noticed any stench since the opening of the canal to amount to anything. There is a great improvement in the river. In my opinion it is purer than it was before. I know those facts in a mechanical way. We don't have foaming in the boilers now nor slimy formation on the coolers or condensers that we formerly had. When I was with the Amer-

ican Spirits Mfg. Co. we operated four distilleries at one time.

3515 The Great Western distillery was located above any of the cattle barns and we had less trouble there than most anywhere else, both with slime in the boilers and in the coolers. The Manhattan distillery was located below the Great Western cattle barns on the river and we had considerable trouble there from water foaming in the boilers and the slime in the condensers and coolers. The Manhattan distillery was located below all the cattle barns except the Manhattan cattle barns and we had a great deal of trouble there. We had our river pipes out farther than any other pipes and we were constantly pulling it up to get out the accumulation of slime and manure and so forth. We have at times pumped nothing but which looked like excrement from the cattle barns up through that pipe. The water is very much better now; in fact I have not heard of any trouble at all lately.

3516 Since the opening of the canal I have had experience only with one distillery, that is the Corning Distilling Company. It is below all the houses that I have named and we have not had any trouble at all.

3517 The length of time a steer is kept for fattening purposes before he is ready for market varies considerably. We formerly kept them nine months, now we endeavor to get them out in six or seven months.

LEWIS A. McFADDEN, examined in chief by Judge Johns:

Have lived in Peoria since July, 1887. Have practiced the profession of physician and surgeon during that time continuously. I was county physician of Peoria county for five years. I was one of the United States pension examiners under President Cleveland's administration; was alderman from the First ward for four years, and also commissioner of health from October, 1901, until June, 1903.

3518 I think when I was County Physician there must have been as many as 500 people living in cabin boats on the

river and along the river. A great many people living on the cabin boats got their water from the springs along the river bank. I found a great deal of sickness among those people prior to January, 1900, more than in any other part of the city. They suffered from malarial diseases, dysentery and typhoid fever. I attributed those diseases at that time to their mode of living and to the use of river water.

3519 The health of those people is certainly as good now as it was before. There may have been some cases of typhoid fever since 1900 but none to my knowledge. Prior to the opening of the canal the water never was good in front or below Peoria, on account of the Peoria sewage which in various ways found its way into the river, and the slops from the distilleries that flowed into it. Since the opening of the canal so far as I could observe, the water above Peoria is about the same as it was before only there is more current. This green scum forms on it now. Some of it is duck weed and some of it is like moss, such as you find in stagnant water in some localities when the weather is warm.

3520 I have examined the statistics of the Health Department since 1895. In August and September, 1895, there were 45 cases of typhoid fever reported to the Health Department. This is a greater number than has ever been reported during the same length of time since. 1896 I haven't got. In 1897, there were 15 deaths; in 1898, there were 18 deaths; in 1899, there were ten deaths; in 1900, there were 17 deaths; in 1901, there were 12 deaths, and in 1902, there were 18 deaths and so far during the present year (1903) there have been 3 deaths. While I was Commissioner of Health, in the families where typhoid fever existed, they were instructed by an officer to disinfect the stools and destroy them by boiling or burying.

3521 There are a great many cess-pools in Peoria. I think one-third of the population of Peoria discharges its sewage into the public sewer system. The contents of the vaults and cess-pools are deposited in the current of Kickapoo

creek near where it empties into the Illinois river. These materials then pass naturally into the Illinois river. About 750 permits are issued in a year for the cleaning of such vaults and cess-pools.

3522 CROSS EXAMINATION by Mr. Jeffries:

3524 The water in the Illinois river is not used by the people of Peoria to any great extent for domestic and drinking purposes.

3525 I don't think the water from the river is any more suitable now than it ever was for domestic or drinking purposes and I would not recommend it. There is a scum in the bogs in the lowlands where the water remains stagnant. The water is not stagnant in the river proper at this time.

3526 The green scum and stagnated condition is removed to a greater extent than formerly by reason of the current in the channel. The appearance of the water has nothing to do with the impurities that it contains.

RE-DIRECT EXAMINATION, by Judge Springer:

Our water is perhaps is not as pure as we imagine.

3527 While we don't use the river water to any extent for drinking or domestic purposes, yet nearly all our ice is harvested from the Illinois river; that is used in and around the city. This ice is used by hundreds of families for drinking purposes, by putting the ice right into the water, and we don't find any bad results arising from that source.

RE-CROSS-EXAMINATION, by Mr. Jeffries:

3528 The ice used here is cut from Peoria Lake, which is a widening of the Illinois river at this point.

3529 W. A. McMILLAN, examined in chief by Judge Springer:

I have resided in Peoria 20 years. Have been sanitary officer of Health Inspector two years under a former administration. I was off two years and I have been at work about a month this last time. The sewage of the town goes through the sewers where they are connected and the garbage is hauled away. The sewage from private vaults and garbage is deposited on

3530 Kickapoo Creek. It is dumped into the deep water of the creek there and finally reaches the river I suppose. In 1899 there were 639 privy vaults cleaned and dumped into the Kickapoo Creek; in 1900, 725; in 1901, 700; in 1902, 735; and so far this year (August 11, 1903) there have been 500 cleaned.

3531 CROSS-EXAMINATION, by Mr. Jeffries:

These figures represent the number of vaults cleaned. There is but one ice plant here in Peoria where ice is manufactured.

3532 EDWARD N. WOODRUFF, examined in chief by Mr. Todd:

Am mayor of Peoria and dealer in natural ice. We have a capacity of 26,000 tons, divided into three locations along the river.

3533 We get our ice from Peoria lake—a widening of the Illinois river immediately above Peoria. I have been in the ice business about 22 years. The water of the Illinois river as compared to its condition prior to the opening of the canal is better than it was. The water is clearer and in better condition in every way. Before the opening of the canal we were hunting for other locations for ice cutting purposes.

3534 This was due to the natural prejudice of the people to begin with. In winter when the river was covered with heavy ice there was always more or less odor to the water. We have had times when there have been a lot of dead fish along the rivers. Since the opening of the canal I haven't observed that odor under the ice.

3535 In my opinion, as an ice man, the water is better beyond question since the opening of the canal. The only objection that we have had to the ice is from the soot that grows on the top and in soft weather gets into the ise and freezes there.

3536 The water today is much better in my opinion than it was prior to the opening of the canal.

CROSS-EXAMINATION, by Mr. Jeffries:

There are two other dealers in town here, one being an artificial plant, with fifty tons a day.

3537 When I say the water is better now than before the canal was opened, I judge from the appearance of the water. I could not tell by looking at the water whether the impurities that were in the water before the canal was opened are in there now. The water is clearer now.

3538 I believe that freezing destroys germs. I pronounce it better ice than it was before the opening of the canal, because the water is clearer and from the fact that I believe that freezing destroys germs.

RE-DIRECT EXAMINATION, by Mr. Todd:

I have never made any experiments in bacteriology.

3539 The other two firms that are cutting ice here I understand are shipping the ice to St. Louis.

3540 PETER CASEY, re-called for cross-examination by Mr. Jeffries:

3541 At the time I was superintendent of the four distilleries in Peoria, the Atlas Distillery and Stark Bros. & Co. were also in existence here. They have for the last six or eight years fed cattle. They fed 2500 head this year. I think they fed the same number last year. They had a contract for five years. There have not been as many cattle fed since 1896 as there were fed in that year. The number of cattle fed has been decreasing right along every year.

3542 I think there has been a slight decrease recently in the corn and grain consumed by the distilleries here. The slop that is not fed to the cattle is dried. It demands a very good price for export.

3543 When we are not feeding cattle, the substance that goes into the sewers and thence into the Illinois river is a water that it is hardly perceptible there is anything in it at all. The cattle we feed are a good quality of cattle and are not diseased if we know it.

3544 The foaming of the water in the boilers before the canal

was opened was caused by the decaying of both vegetable and animal matter. I don't know from any examination that those same impurities are not in the water now, but the action is entirely different, is all we go by. I don't think the water in the river is as much polluted now as it was before the canal was opened. In fact I know it is not. I know only from observation and for mechanical purposes. The rapidity of the current now carries away these impurities that were in the stagnant places and it did not carry it away before in low water.

3545 ROBERT R. MARTIN, examined in chief by Mr. Todd:

Am chief engineer of the Peoria waterworks. E. J. Cain and myself took samples of water for the Sanitary District. The water was taken from the Illinois river in the channel at Averyville, above Peoria, adjoining Shady Beach. (Witness states method pursued, places where samples were taken, how marked and shipped, etc.)

3550 E. J. CAIN, examined in chief by Mr. Todd:

(This is the person referred to in the examination by Mr. Martin.)

3551 ROBERT R. MARTIN, recalled for further examination by Mr. Todd:

Have been acquainted with the Illinois river for the last 15 or 16 years. I have worked along side of it. I have pumped it into the city mains and have been quite a fisherman.

3552 Prior to the opening of the canal in the winter time when the river would be frozen over here, the fish caught above Peoria would have a tarry, gassy taste—so much so that they were not fit to eat in the winter after the ice was frozen over for a short time. This winter we have had fish once or twice a week at our house and they have not that taste now. We relish the fish as much in winter now as we do in summer. The water is clear now; before the opening of the canal it had an odor to it. Its condition is a great deal better now. I haven't observed any odor. I think the effect of the Drainage canal has been to give us a better river—better water. I don't know whether it has any

effect on the mosquitoes. In the last few years we have had less mosquitoes up here.

CROSS-EXAMINATION, by Mr. Jeffries:

3553 The fish used to be all right in the summer time when they had plenty of air. When I say the water is better I say so from drinking it. I am around the river all the time. I have charge of about 4500 feet of river frontage.

3554 I am chief engineer at the Water Supply Pumping Works.

3555 We pump an average of four to six million gallons a day for the last two years.

3556 CHARLES F. HIXSON, examined in chief by Judge Johns:

Reside at Peoria. Run a summer resort at Shady Beach. Shady Beach is about three miles and a half above Main street. We are right at the Narrows. The condition of river above the Narrows before the opening of the canal in the summer

3557 time when the water was very low, the water became very foul and had a very bad odor to it, and there would come a very heavy green scum through the months of July and August particularly; a man get up in the morning there at 4 o'clock or daylight, the odor that come from the river was something fearful. In winter time when river was froze over fish were not fit to eat; tasted tarry and gassy. Lots of them would die. When ice broke up in spring you would see thousands and millions of dead fish floating in the river. Since the canal was opened it has been very much better; we have a higher stage of water. The water has been purer to the naked eye, and clearer; and we haven't that odor coming from the river that we had prior. We have had no trouble in regard to the fish since. I was engaged by Jacob Harman to take samples of water at the Narrows. (States method pursued and manner of shipping samples, etc.)

3560 CROSS EXAMINATION by Mr. Jeffries:

Before the canal was opened the water in the river at this point was stagnant at this time of the year, very low. It is

much better now; there is a good current and there isn't the odor that there was before.

3561 WILLIAM BAKER, examined in chief by Judge Johns: Reside at Peoria. Am Inspector for the State Board of Live Stock Commissioners. I have general supervision of the stock on foot that passes through the yards. I can't say that I officially inspect the stock that is fed here by the distilleries. That stock does not go through the stock yards as a rule. The Peoria Stock Yards are located at the foot of South street and the river. The entire stock yards would be about two blocks wide and 4 blocks long. The yards have their divisions for cattle and others for hogs and sheep, laid out for convenience. I would say 6,000 hogs are received a week and from 300 to 600 cattle and probably 100 sheep. The manure and urine from these animals goes into a catch basin and into the sewers and from there into the Illinois river. That part of the material which is hauled away from the pens is hauled below or near around the river bank. To a certain extent some of it is washed off into the Illinois river by the high water. The balance fills in a low portion of the ground that is located there. Some material is dumped on one side of the C., R. I. & P. railroad track and a part of it is dumped in the river and a part on the river bank. The seepage of that would naturally have
3563 to pass into the Illinois river. By seepage I mean the seepage from the general dumping of the offals which are hauled from the pens. There is one team hauling this offal all the time.

3564 The live stock that goes through the yards is mostly cow stuff and a great deal of through cattle that are unloaded here for resting and watering purposes. The yards are located below the city.

3565 PERCY M. SWAIN, examined in chief by Mr. Todd: Am captain of the steamer Fred Swain, plying between here and La Salle. Prior to opening of canal in 1900 there was very little current and there was a green scum
3566 formed on the river and the water was not clear; more

of a sewage color; and in places it had a greenness and also this white stuff; and considerable odor came from the water. In winter time when river was frozen over there was more or less dead fish and more or less odor. The river is altogether different now than it was prior to the turning in of the drainage. It is clearer and this green scum doesn't form any more, only in places like for instance, Lake Depew, or for instance the Illinois river where there is no current; that would be in eddies, you know. Heretofore it was necessary to clean boilers once a week; but of late once in two weeks is sufficient. We fill buckets on the boat for fire purposes. It evaporates as much now, but there isn't so much of this greasy appearance around the edge of the buckets as there was heretofore.

3567 The water is clear. Lots of times you can see right down to the bottom. Prior to the drainage canal you couldn't see the bottom of the river at any place at all. Since the opening of the canal the condition of the water is better. There is more or less current and this green slime doesn't form any more on the river; it is a good deal clearer and better in every way. I was down to the stock yards yesterday. Above the bridge the water is considerably different from the water below the bridge. Below the bridge where it gets the sewage from the stock yards and packing houses, it is a thick, heavy, mushy appearance. Two or three hundred feet from land you can see this stuff bubble up. It has a black appearance; an awful appearance. We always stop the pumps before getting in there, to keep from pumping this stuff into the boiler and causing a stoppage of the pipes. And it has a kind of rotten smell coming off of it.

3568 I suppose that is caused by the turning in of those distilleries and cattle pens and packing houses; that stuff accumulates there, that thick refuse. At times you can see this sewage coming out of those runs. At this time the river

3569 above the bridge is clearer. Below those stock yards and still houses, it is very sluggish and as I said before, it has this odor coming from it; it is filled up.

CROSS-EXAMINATION, by Mr. Jeffries:

The volume of water and the current of the Illinois river is much greater now than it was prior to the opening of the canal. From Peoria to La Salle there was very little current before the canal was opened. There is considerably more current now. Where the water is dead there is some scum, and in the eddies and up in the sloughs. This scum, I suppose forms only where there was no current or where there was very little current. The water is considerably clearer and that odor doesn't come from the water as it did before, and we don't get this slime. I
3570 don't know what particular ingredients are in the water. The water has been more or less purer than it was heretofore.

3572 ALEXANDER RICHARDSON, examined in chief by Judge Johns:

Reside at Peoria. Have been in jewelry business. Have fished on Illinois river for 30 years, annually and hunted and fished for 15 to 20 years. The condition of the water be-
3573 fore opening of canal was very bad, extremely bad, in my opinion. Water was very low at certain seasons of year; at some points covered with green scum clear across; at some places near the city, up above the city, you could smell it here, a very bad odor. Before opening of canal unless we caught fish around the springs we couldn't eat them at all. Before opening of canal there is no doubt but that the water was always very bad below Peoria, that is below the stills at Peoria, for a number of miles. It was bad above Peoria and a good deal worse below. There was an odor to the water and scum formed on it below the city. Since opening of canal the water in the Illinois
3574 river above Peoria is virtually a new stream. There has been so much larger volume of water, and so much greater current, that we find the water is purer, colder and better in every way. The green scum does not form and I haven't detected any odor. The condition below Peoria is like it was above; it is wonderfully improved. I might add that it is not what it ought to be on account of the refuse from the distilleries. On

real hot days I have noticed an odor. The fish in the river are now harder and firmer and of a better flavor and we catch larger fish, such as bass and pike which we didn't catch before.

CROSS-EXAMINATION, by Mr. Jeffries:

3575 I don't know anything about the sanitary condition of the river from analyzing it, but I know from its appearance and its smell.

3576 MICHAEL D. HURLEY, examined in chief by Mr. Todd: Live in Peoria. Am doing special work for the fish commissioners. Before that I was captain of police in Peoria and before that wholesale fish dealer. Prior to the opening

3577 of the canal, below Peoria the Illinois river at low stage was muddy, mixed with manure and what we used to call slop. It was pretty strong smelling. Above Peoria in Peoria Lake and the lakes above here, it was covered with green scum during the warm season. The water itself looked green. It smelled badly with a different smell than below. There were times both winter and summer that fish used to die in numbers; in the winter more particularly above Peoria; in the summer, just from the distilleries on down. Since the opening of

3578 the canal there has been an absence of the scum, and the smell has disappeared almost altogether, except a little below the city proper here. The water was clearer apparently, and better. There are two bridges below Peoria. Below the first one the water is now quite good and a little below that it is bad. It is riley and muddy and discolored somewhat. That condition is noticeable pretty well all the way down the river to the Havana territory. Opposite the distilleries the condition of the river is bad. It is filthy; lots of bubbles; plenty of those little patches of bubbles floating down all over. That condition continues pretty well down to Pekin; then it clears up somewhat, and then it begins again and extends below Pekin for six or seven miles. The water above Peoria seems clearer and better in every way than that below Peoria. Knowing the river as well as I, my opinion is that the opening of the canal has had

the effect of purifying it. I think it is true to a considerable extent below Peoria as well as above.

3579 CROSS-EXAMINATION, by Mr. Jeffries:

In the spring time, in flood tide the volume of the water is about the same now as it was before opening of the canal. At low water season, the water is somewhat higher. There is more current. I base my knowldege of the purity of the water from experience. It made several people sick before and I have not known any to be sick since.

3582 I only know of the ill effects before and of none since.

3583 CHARLES F. BARTSON, examined in chief by Judge Johns:

Live at Peoria. Am in the saloon business. Was formerly in wholesale fish business. Before opening of canal the water in the Illinois river below Peoria and down the river from Copperas creek dam was a great deal lower than it is now; the conditions that exist down there now are as they did then in regard to fishing. There was a sort of slime accumulated on the

3584 nets. Below Peoria the water was green and there was an odor to it. Whenever we got a bad winter it killed a great many fish. When there was ice on the river they got so bad we couldn't use them. It was a common thing to have fish die in summer. Above Peoria the water was low and had a green scum on top. Did not have an odor. Couldn't keep fish long in live boxes.

3585 Since opening of canal the water below Peoria has been a great deal higher and I have never seen any of the green scum on the river like it was heretofore. The slime is still there. Above Peoria there is more water and I have never seen it green or with a scum on it since the canal was opened. In the winter the water is good under the ice. No fish have died under the ice that I know of. The fish live longer in live boxes. The

3586 fish are stronger and healthier since opening of canal.

Before opening of canal I drank the river water and it caused me a spell of sickness. Since the opening of the canal the water is better for drinking purposes. The condition of health of people living on the river has been better. I haven't known of any typhoid fever among the fishermen. Before the opening I knew of one case sure and a few others that they said was typhoid. The health of fishermen is better as compared with that of people following other pursuits.

3587 CROSS-EXAMINATION, by Mr. Jeffries:

There has been a very large increase in the volume of water since the canal was opened and a very great increase in the flow of the current.

3588 I. N. FEGER, examined in chief by Judge Johns:

Reside in Peoria; am in electric business. Have fished

3589 upon Illinois river all my life—from Havana to Henry.

Prior to opening of canal the water in the Illinois river above Peoria I considered bad. It was scummy and green and sluggish and had an odor. The fish above Peoria were bad; they were soft and I have known them to bury lots of them. At Pekin the city had to hire people to go and bury them. I considered the water below Peoria bad too. It was a yellow scum; bad odor. Since opening of canal the condition of the river below Peoria has been much better. Fish are better too. The fish above Peoria and the water has been good. The water above Peoria is and has been better than the water below

3590 Peoria.

CROSS-EXAMINATION, by Mr. Jeffries:

When I say the water is better now I say so from the fact that there is a better current, a larger volume of water and the water is clearer. I know nothing of the chemical or bacteriological properties of the water. Don't know whether the filth from Chicago has polluted the water with disease germs or not.

R. R. BOURLAND, examined in chief by Judge Springer:

Reside at Peoria. Am in real estate and loan business. Am Secretary of Illinois River Valley Association. The object of the association is to look after the interests of the residents in

the Illinois Valley in relation to the use of the river itself. Have been connected with the association since 1897. Lived in Peoria all my life. Before opening of canal Illinois river
3591 was an ordinary, sluggish stream that was disagreeable in low water. The river above Peoria was as I said an ordinary prairie stream; below Peoria it was very much affected by the drainage of Peoria, and was a much more disagreeable stream below. There was certainly an odor from below Peoria; I am not so positive as to the fact of the odor coming from above. Since 1900 the water above Peoria is certainly a great deal better than it was prior to that time. The water is clearer in color and does not get so low at low water, and therefore does not have disagreeable features of the former low stage of water. Below Peoria since 1900 the waters still show the effect of the offal from the factories, but not to the same extent as before, because of the greater volume of water, and I
3592 find the odor not nearly so apparent as it formerly was. Before 1900 the use of the river for pleasure craft was almost entirely given up during low stage of water. Since that time there is continual use of the river by a great many people for pleasure purposes—using house boats for summer residences. A great many people also row for pleasure.

CROSS-EXAMINATION, by Mr. Jeffries:

3594 I think the opening of the canal has raised the water in the river about two and one-half feet in low water and in high water it is absolutely impossible to estimate it. The current in the narrow part of the river has materially increased.

3595 When I say the water is better I simply judge from its appearance and also make that statement that it is better for the purposes to which the river might be employed.

JOHN D. McCLURE, examined in chief by Mr. Todd:

Am in real estate and loan business. Have lived in Peoria 53 years. For 53 years I have been on the river every year. Before opening of canal the Illinois river was at times very offensive; a green scum would form on it and a sticky, gassy smell to

it, especially in low water and when ice was on the river. Since the opening it has been very much improved; the water has been better; at least there is not so much of a smell and not so much scum forms as there did before. The water appears purer.

CROSS-EXAMINATION, by Mr. Jeffries:

There has been a better current and increase of volume.

3597 JUDGE JOHNS: I now hand the Commissioner envelope containing 26 tickets, which it is admitted were made by witness Charles F. Hixson, and which would have been identified by him in his testimony today if the tickets had been present.

Envelope marked State of Illinois Exhibit No. 11 for identification.

NAT H. COHEN, examined in chief by Judge Johns:

Am President Illinois Fish Commission, reside at Urbana, Ill. Been commissioner since 1897. Prior to that time was familiar with Illinois river. The wardens make reports

3598 to me. The steamboat Illinois is employed by the Illinois Fish Commission to patrol the river for the enforcement of the law and to collect fish for distribution from the

3599 overflows of the ponds and lakes adjacent. Fish are collected by a crew, with a seine. These fish are afterwards distributed to various waters of the State. From Grafton to La Salle is as far as the Illinois boat can navigate. Before opening of canal above Peoria the Illinois river in the spring during the freshet I couldn't tell much difference in the water, but as the summer came on and water receded from the banks, the water became stagnant, little or no current, covered with a green scum and with a bad odor. The lakes adjacent were low, in a very high temperature, destroying fish from decayed aquatic matter; destroying what we term plantain. Plaintain is the vegetable and animal life in the water that the fry, the small fish, live on. The temperature becomes so high that they are all destroyed. I have found thousands of dead fish in lakes adjacent to the river from this cause. Since that time the temperature in those same lakes is much lower; the water much

clearer and we find an absence of dead fish. Above Peoria before opening of canal a scum formed on the water. Duckweed also formed. There was also a scum that is usually on stagnant water. The water had an odor. The fish didn't have the tenacity of life they have now and as a general thing the coloration was much lighter. Since the opening of the canal the
3601 water above Peoria seems to be clearer, the temperature lower, and a stronger current. The fish are much better, those that I have seen. The temperature of the water in the sloughs and ponds which are filled up by the overflow is lower now because they have an inlet from the river. Before opening of canal the condition of the Illinois river from Peoria to Pekin was very foul. Had bad odor, green scum and frequently
3602 we find dead fish floating. From Pekin to Copperas creek it was bad too. We would find floating islands, being refuse from the distilleries of Peoria, as far down as Copperas creek. The water from Copperas creek to La Grange was better than from Peoria to Pekin. The water improved as it went down. There was some odor in the river and some scum on it almost as far down as Grafton.

3603 Before the opening of the canal the fish between Peoria and Copperas creek were of a light color and not as healthy as they seem at present. When the temperature goes up from 90 to 110, it is hard for fish to exist and the temperature was sometimes as high as 90 to 110 degrees Fahrenheit. Since the opening of the canal the water between Peoria and Copperas creek is much improved. There is a large amount of stuff cast into the river at Pekin from distilleries and city sewage. Since the opening of the canal the water between Copperas creek and La Grange is much better than that above Copperas creek. Since the opening of the canal the fish are much better, of finer color, have more tenacity of life and I regard them as healthier and better than ever before. The water between La Grange and Kampsville is better than that between Peoria and Copperas creek. The water improves as it goes down.

3605 In my observation of the Illinois river the waters as they travel from sources of impurity tend to purify themselves. We occasionally find a herring from Lake Michigan but the conditions of the Illinois river are not suitable for the fish of Lake Michigan.

3606 There is a great deal of land overflowed all along the river from La Salle to Grafton.

3607 There are from five to ten thousand people employed on the river from La Salle to Grafton, and bringing into the State probably $500,000 and shipping out from twelve to fifteen million pounds of fish per annum. The people who follow this business usually live along the river in cabin boats and in villages, the larger number living in cabin boats. From the information I get along the river, they say there is less malaria and scarcely any typhoid fever among the fishermen in the last three years. They tell me they drink the water now and they could not drink it then.

3608 CROSS-EXAMINATION, by Mr. Jeffries:

There is a much swifter current now than there was before. You could hardly tell which way the current went in the summer months. There has been quite an increase since the opening of the canal. When I say that the river is better since the opening of the canal I say that from the fact that the current is better, the temperature of the water is better, and from its appearance, and the fish are better.

3609 As to whether or not the sewage from Chicago contaminates the water, I do not know anything about it. Game fish will not live in anything but pure water and they will not get the color they have got unless the water is pure. Bass will thrive only in pure water and if the water should be foul and there is a spring close by, you will always find the bass in the pure water.

3610 DR. FRANK C. BOURSCHEIDT, examined in chief by Judge Springer:

Am a physician and surgeon. Have resided in Peoria since 1874. Was Health Commissioner from 1898 to 1901. Have

ade a special study of chemistry and bacteriology. I don't ink there is much difference, if any, in the death rate at Peo- a before and after the opening of the canal from enteric dis- ses. The period to which I refer relates to the time since the resent waterworks system was established. At the present me, the supply of water is obtained from wells which intercept ie spring water, which comes from this high plateau north of ie city. Our water supply has nothing to do with conditions the Illinois river.

CROSS-EXAMINATION, by Mr. Jeffries:

I was not Health Commissioner 12 years ago, or at the time he present system of waterworks was established.

RE-DIRECT EXAMINATION, by Judge Springer:

I have not known of a case of typhoid fever among those ersons who reside on the banks of the river or in house boats. Deaths from typhoid fever were recorded officially to the Board f Health. While I was in office there was not a body buried vithout a permit and the cause of death.

RE-CROSS EXAMINATION, by Mr. Jeffries:

3612 There has not been any increase in typhoid fever since the opening of the drainage canal since I was health officer. I stated I did not know of a single case on the river bank where they use the river water.

HENRY B. OCKER, examined in chief by Judge Johns:

Reside at Peoria and my occupation is that of land agent. Was engaged to take samples of water in the Illinois river by Dr. Long of Chicago. (States where samples were taken and method of taking and transporting same.)

3618 S. P. BARTLETT, examined in chief by Judge Johns:

Reside at Quincy and am Field Supt. of United States Fish Commission, which position I have occupied for about 31 years. I am also a member of the Board of State Fish Commissioners and have served consecutively for 24 years.

3619 We have no hatcheries in Illinois, but we have retaining ponds at Meredosia. As a member of the State Fish Commission, my duties are the collection and distribution of

indigenous fish and the management of the Commission's boats. Prior to July, 1903, the fish wardens along the Illinois river, under the supervision of the Fish Commissioners would average one to each county, and perhaps two or three that had entire jurisdiction of the river.

3620 In the employ of the Fish Commission, in the summer, there are about 150 people. I have been intimately associated with the Illinois river for over thirty years. Prior to the opening of the canal in the early spring, the current at times would reach a mile or a mile and a half an hour. Later in the season when the water was lower, it has been frequently impossible to tell which way the current was going. It was very sluggish and very slow. There are four dams in the Illinois river.

3621 The Henry and Copperas creek dams were built by the State of Illinois; those at Kampsville and La Grange were built by the United States. In low water the effect of those dams would be to make the current of the river very slow. At high water, there would be no perceptible effect. The effect would also be to make slack water at a very low stage of water. Prior to the opening of the canal, the river between La Salle and Henry dam was about on the average of river water. There was an odor more or less, as I remember it at low water times.

3622 It came from decaying vegetation and refuse matter dumped into it. I have seen the stage of river so low in the Illinois river during the winter season that the fish would perish under the ice. The condition of the fish between La Salle and Henry would vary with the different seasons. I have known fish to die there previous to the opening of the canal. Fish are very susceptible to the condition of the water in which they live. It is nothing uncommon to find fish taking on a coloration from the character of the water they are in. The temperature and condition of the water have a material effect on the coloration of the fish.

3623 The strong fish always have a dark bright color. Judging from personal observation, and going over it fre-

quently, my judgment would be that the water of the Illinois river above Henry dam shows a decided improvement in every way since the opening of the canal.

3624 Since the opening of the canal my observation has been that the water is frequently better and clearer between Henry and Peoria Narrows. The fish seem to be in good merchantable condition. At Peoria there are foreign substances deposited in the river from all sources. The sewage is very large. The refuse from the gas houses and distilleries and glucose factories is immense.

3625 I have noticed this foreign matter in large quantities below Peoria. I met this condition of pollution frequently as far down as Havana in limited quantities, of course. I am talking of this floating substance on the water—those islands. I have seen a very heavy scum on the water below Peoria and at Peoria, which I believe to be the sewage and refuse from those places at Peoria. That did not go down very far.

3626 I have met with it at Pekin and below perhaps. It was a kind of broth. It looks like grease on top of the water. Since the opening of the canal the condition of the water below Peoria, as far as Pekin, has been improved. I have seen some floating stuff in the river but nothing as bad as it was prior to the opening of the canal. This particular refuse from the gas works, distilleries and glucose works is run off in spouts at the edge of the water and allowed to accumulate there and when the very low water comes, it breaks off and floats off with the current. That would be an impossibility if the stage of the water was of sufficient height to keep the shores clean. I attribute the absence of it now to the better condition of the water and the swifter current. To the best of my recollection I have seen the substance cast into the river at Peoria floating just above Havana, but it was not in great quantities nor in large pieces.

3627 There are a number of lakes below Peoria and above Copperas creek dam which have natural connection with the river. Spring Lake is the one containing the greatest area.

Prior to the opening of the canal this lake was affected very materially by the cast off matter from Peoria and Pekin. If the water was rising, this stuff would break off from the shores very easily and was taken in great quantities into this lake. In fact I have seen it in sufficient bulk, in the canal leading into the lake, to prevent our going in with boats. We had to break it up before we could get by. It floats off into the lake and with other impurities makes the lake very foul at times. (Witness states bad condition of Spring Lake a number of years ago when an investigation was made thereof.)

3628 The artificial canal leading into Spring Lake is about four miles above Copperas creek dam.

3629 Since the opening of the canal I have made inquiries into the condition of Spring Lake, both above and below the revetment where this pollution entered the same.

3630 About ten years ago, some of the black bass I took from this river, upon post-mortem examination disclosed that all of the digestive organs of the fish had been absolutely dissolved. The men sickened in making a haul of fish at that place. Since the opening of the canal I do not believe there has been a season when any dead fish have been found in the lake. The water is very much clearer and an examination of the bottom, while it shows quite a deposit, is very slight as compared to the season of which I spoke. Before the opening of the canal, between Copperas creek and La Grange there would be a great deal of vegetable growth in the water and in a good many places fish would die from the high temperature and the decaying vegetable matter.

3631 Since the opening of the canal there has been a much greater volume of water and the water has been much better and there has been a great decrease of various kinds of vegetation. The best evidence that we have of the increased betterment of the water at points below Copperas creek is the fact that there are more black bass in the river this year than I have ever known. Before the opening of the canal the water between La Grange and Kampsville, except in very low water,

was classed as fairly good. Before the opening of the canal the lakes and bayous between La Grange and Kampsville varied according to the seasons. Some seasons the water became very bad from decaying vegetation and very foul and very destructive to fish life. Since the opening of the canal the condition has been in my opinion good.

3632 The fish between La Grange and Kampsville, since the opening of the canal, have been in fine condition. As I stated a moment ago, there are more black bass, which are inhabitants as a matter of choice of only clear water. The ponds and bayous have been higher and the fish propagate better. Between La Salle and Peoria, since the opening of the canal the character of the water is improved, until we get to Peoria Lake we get a practically good water. Between Peoria and Copperas creek the water improves as you get close to Copperas creek. The water below Peoria from Peoria to Copperas creek dam is very considerably worse than that in Lake Peoria. Except under extraordinary conditions, there is very rarely a better body of water found anywhere than in Peoria Lake. The water gets better all the time as you go farther down the river. A man does not have to be an expert to notice that.

3633 (Witness states condition of the Illinois river in 1877.)

3634 In 1885 the city of Chicago commenced to pump water from the Chicago river into the Illinois and Michigan canal, which emptied into the Illinois river. The drainage canal has increased the volume of the Illinois river very materially and has accelerated the current. I have a very large acquaintance with fishermen from La Salle to Grafton. There are from 2,500 to 3,500 people directly interested in fishing themselves, which does not include the helpers. All told there would be 5,000 people—this would be a fair estimate. Before the opening of the canal we had a great deal of sickness among our men. Not much typhoid but a great deal of low grade fever. I was going to say as a physician—but from what knowledge I have, this was owing to the very bad stage of the water during low

water. I have never practiced medicine. I was educated and graduated as a physician.

3636 Since the opening of the canal my observation has been that there has been a very great decrease in typhoid and intestinal diseases among the people engaged in the fishing industry on the Illinois river.

My work carries me to almost every town along the Illinois river and in my talk over semi-professional matters with physicians, every one of them has commented on the decrease of typhoid and malarial fevers during the last two or three years.

3637 The health of my own men has been very vastly improved. From all sources of information I should say that the health of the fishermen generally has been a great deal better. In my opinion there are more than 5,000 people in tents and flat boats or in house boats on the sloughs and bayous, bays and lakes connected with the Illinois river. In my opinion the health of that class of the population has improved since the opening of the canal. The towns along the Illinois river are much sought after as resorts for pleasure fishing.

3638 The interest in fishing and sport on the Illinois river has been great and almose every available lake on the river of any size, has been taken for a pleasure resort. They build either club houses on the bank or house boats. The Illinois river is very peculiar in its formation, in that it has flat shores on both sides of the river. These bottoms extending from three to fifteen miles in width and filled almost in every case, with lakes and sloughs, aside from the river itself. As the fall is only a half inch to the mile, the overflows are very frequent and the lakes fill up and evaporate again several times during a season, during the dry seasons. The course of the river is inclined to be free from bars and of a very even depth. The land on both sides of course, on account of frequent overflows, is very much as nature left it. The river in extreme high water will sometimes be 12 to 15 miles wide.

3639 The country adjoining the Illinois river is devoted to agriculture. Domestic animals, adjoining the river are

customed to drink these waters. The lowlands in some places are used for pastures during low water.

3640 Cattle are brought from a distance in the seasons of low water for the purpose of being pastured on the lowlands f the Illinois bottoms. I have never heard of anthrax among ttle along the Illinois river, nor have I ever heard of any dis- ses among cattle drinking the Illinois river water, which were ttributed to the drinking of the water of the river. The in- rease in fish in the Illinois river has been very great in the last hree years. In 1901 the report of the Fishermen's Association -an organization of about 1,000 men on the Illinois river, gives total of eighteen million pounds of coarse fish caught, with quite a per cent of fine fish, as well.

3641 (Witness withdrawn.)

WILLIAM H. BINNIAN, Examined in chief by Mr. Todd.

I am connected with two companies manufacturing agri- cultural implements and straw board. I am President of the Acme Harvesting Company, which employs about 700 men and also President of the Peoria Straw Board Company. Have lived in Peoria 46 years.

3642 Before the opening of the canal we considered the Illinois river a pretty foul stream—quite sluggish. The river was very much more filthy below the city than it was above, on account of the refuse thrown in by the manufacturing plants on the river bank. To all appearances the opening of the canal has cleared up the water in the Illinois river very materially and practically we have found it has been a very great benefit, particularly through the straw board mill. Before the canal was opened I took my family on the river once in a while under protest from them. Since the canal was opened, I don't hear any objections. Prior to the opening of the canal it used to cost us from 50 cents to 60 cents per ton of board for felts and our average cost now is 27 cents per ton for felts.

3643 The life of a felt now is about five to six weeks when formerly it was but three to four. The water formerly

rotted them more quickly than it does now, on account of the impurities of the water. In regard to the machinery, our bills for repairs are much lighter than they used to be. The present water does not have so evil an effect on the valves and pipes as the old water had. They do not rot out as quickly and do not wear out as quickly.

3644 The water used in the harvesting plant for condensing and steam making purposes is secured from the Kickapoo Creek. This creek receives its supply of water from the back water of the Illinois river and from surface drainage up in the country. I am firmly convinced that the quality of the Illinois river water at present is far superior to what it was prior to opening of the drainage canal, by practical experience and scientific tests that have been made at both plants at times.

3645 I don't think the water can be excelled for manufacturing purposes and for steaming purposes. We use about two millions and a half gallons of water per day at the straw board plant. The refuse from the straw board factory is thrown back into the river. This refuse is impregnated with lime and the washings from the cooked straw which takes off the silica and other refuse matter of the straw. The Acme Harvesting Company is a mile and a half from the lower city limits and the straw board factory is in Averyville, a quarter of a mile above the city limits.

CROSS EXAMINATION, By Mr. Jeffries.

3646 I don't know the character of the impurities in the water before the opening of the canal. I simply testify to the facts on the mechanical side of it. Before the opening of the canal there was very little current in the river. The current now is much swifter.

3647 S. P. BARTLETT, resumed the stand for further cross examination by Mr. Jeffries.

3649 Nearly all the bottoms of the Illinois river are used for pasturing cattle and hogs. The current in the Illinois river has increased since the opening of the canal. A large amount of the damage above Peoria, before the canal was

opened, was due to the decomposition of vegetable matter. Below Peoria, that is the worst, the greatest amount of damage is done in my opinion from the offal and refuse and whatever escapes from the sewers of these manufacturing institutions.

3650 My own personal opinion is that outside of the manure and slop and offal from the cattle pens, some of the most destructive elements come directly from the sewers of Peoria and from the gas houses.

3652 W. F. YORK, Examined in chief by Judge Johns.

Live in Peoria; am a licensed captain and pilot on the Illinois river. Have been afloat on the river since 1850. I have traveled the entire length of the river. Before the opening of the canal the water was pretty sluggish and dirty. No current in it, and a green scum on it. It smelled badly above Peoria. Did not stir at all. It just lays around rotten and full of all kinds of insects.

3653 The water above Peoria was not as good then for steaming purposes as it is now. We had to clean the boilers every week. Since the opening of the canal above Peoria, the water has been better for steaming purposes. We get lake water instead of river water and slough water. The lake water is purer water. Before the opening of the canal below Peoria as far as Copperas Creek it was just about a sewer. It was full of offal and manure and hay and everything that comes out of cattle and hog pens. Bad, dirty and very bad smell. There were islands of this stuff in the river. It was bad for steaming purposes. The boilers would foam. Since the opening of the canal below Peoria, it has been considerably better than it used to be, purer and not so much dirt in it. We have never had any trouble since the canal was put in. There is three feet more water and about a mile more current. The boilers do not foam now.

3654 Between Copperas Creek and La Grange, before the opening of the canal the water was pretty dirty. It was better than it was above Copperas Creek. If you got a 7 or 8 foot rise out of the Missouri you would have some more foam after

you went below Madison. When there is a raise in the Missouri or Mississippi river the water from those rivers backs up the Illinois for 30 or 40 miles.

3655 CROSS EXAMINATION, By Mr. Jeffries.

The boilers would not foam in the spring of the year when the water was high.

3656 You would find this green stuff on the water when the water was low and there was no current to carry it off.

3657 ISAAC TAYLOR, examined in chief by Mr. Todd:

I reside in Peoria. Have been in the real estate and loan business 33 years. Have been canal commissioner and also on special commission to inspect the Chicago Drainage canal. I have been familiar with the Illinois river from 1850 to the present time. Am chairman of the Illinois Valley Association. I was one of the committee appointed by Governor Tanner to inspect the drainage canal and report to him as provided by law under which the Drainage canal was constructed. Our duties were to inspect the Drainage canal and ascertain if the Sanitary District had complied with the law in the construction of the canal. We employed an engineer in chief and made complete surveys and a full investigation following the requirements of the law, and found that the law had been complied with.

3659 As a member of the Valley Association, I made an inspection of the Illinois river during the summer and fall of 1901 and have made frequent inspections of the river since that time. This was for the purpose of ascertaining the character of the water as compared with the water before the Chicago Drainage canal was opened, and also to make some estimate of the amount of the flow. I will add to that the effect of the flow upon the Illinois river. Before the opening of the canal the water in the Illinois river was low, bad looking and bad smelling. It was more noticeable from La Salle to Henry and it was also noticeable from Henry to Peoria. From Peoria down it was in bad condition.

3660 When the water was low from Peoria down to Copperas creek, the water was of a bad character with consider-

able sediment in it. That condition obtained to a certain extent all the way down to Copperas creek. The turning in of the waters of Lake Michigan through the Drainage canal has made the water very much clearer and very much better. The water above Peoria in Lake Peoria at the present time is in very bad condition. There is no odor discernible. As to the condition below Peoria, I could not testify so definitely in regard to that, only that the water has a dark appearance; it is darker than above Peoria. The condition below Peoria is much better today than it was before the opening of the canal. The river has a larger flow of water. I estimate it from two and a half to three feet deeper, the water is clearer and better in every way for navigation and sanitary purposes.

CROSS-EXAMINATION, by Mr. Jeffries:

(Witness states manner in which the commission made investigation as to whether the Sanitary District had complied with the provisions of the law in relation to the construction of the canal.)

3664 E. M. WYATT, examined in chief by Judge Johns:

Reside in Peoria and am on the Health Department at present. Was an inspector at the stock yards from 1897 to 1901. The stock yards I should judge are about a block and a half each way, perhaps two acres and a half in the yard.

3665 There are two packing houses and one slaughter house near there. My duties were to look after the diseased animals that were shipped in. I have heard of anthrax but I never knew of it here. The cattle that were brought here when diseased were affected with lumpy jaw, sore eyes and lung trouble. The number of cattle brought here for home consumption would average from 500 to 700 a month. In addition to that would be through cattle stopping here in transit. I should judge that 15,000 to 25,000 hogs a month pass through these stockyards and very few sheep. There were some cases of hog cholera.

3666 The animals infected with that disease were generally killed and sold for people to eat; the scalpers would buy them. The packing houses never bought them and packed them. There were catch basins to take the water out of the yards and out of the pens. The drainage flowed finally into the river. The dirt and cobs on the floor were hauled out and thrown on the river bank.

Goden & Sons kill anywhere from three to five hundred hogs a day and the other firm about the same. Perhaps those two firms kill 300 cattle a week. The sewage from these three institutions is emptied into the river.

3667 Some of the privy vaults are connected with the sewer system and some are hauled and dumped.

CROSS-EXAMINATION, by Mr. Jeffries:

At the public slaughter house I speak of, they kill stock for anybody that brings it around. A great many of the hogs that the farmers kill for winter use are brought here to be slaughtered. The butchers that do their own butchering go there and have it done.

3668 There are no diseased cattle killed there that I know of, only what are caught by the inspector and taken there to be killed, then they are postmortemed by the Assistant State Veterinarian. Those that have sore eyes and lungs are generally condemned; they are steamed and pressed and sold for fertilizer.

3669 R. D. CLARK, examined in chief by Mr. Todd:

Am General Manager of Clark Bros. Company's distillery. Have been in the distilling business since 1892.

3670 I am also President of the Thomas & Clark Cracker Manufactory and President of the Peoria Board of Trade. We feed one steer about 275 (?) gallons of slop and 8 pounds of hay per day. This slop contains about 12 to 13 pounds of solids. During the last five years the cattle fed in Peoria would average about 10,000, perhaps a little more. In the fattening of 10,000 head of cattle, we use about five carloads of salt a year. About 140 barrels to the carload.

3671 Most of the excreta from the cattle runs over the bottom land back of the distillery. That disposition has been made of it for two years. We feed 600 head of cattle at one time. When we fed in the old distillery the offal ran into the river. The excreta of the cattle fed in the other distilleries in Peoria runs into the river. We have no connection with the river whatever in the mashing of grain for distillation purposes.

3672 All the distilleries use Illinois river water for boilers except myself. Have used river water in the rectifying house for four years. The water since the opening of the canal has been better for boiler purposes. The boilers do not foam as they used to. In my opinion I think it must have been the organic matters in the water that caused the boilers to foam. On investigating this subject, I find that there are three principal things that make boilers foam; one is sodium carbonate, one is organic matter and one is an alkali. I don't think we have enough sodium carbonates or alkalies in the water to make it foam and therefore I judge it must be the organic matter. Our principal scale forming substances are carbonate of lime and magnesia, and sulphate of lime and magnesia. Since the opening of the canal the scale forming in the boilers and machinery seem to have a little different color to it. I do not hear of any complaint about foaming now. My opinion is that the Illinois river water now is very much improved for steam purposes. Before the opening of the canal the water between Peoria and Henry during high water was good, but a trifle muddy. During the low water stage there appeared a sort of green scum which would foam and bubble after the boat which I have not noticed of late. There was considerable odor to the water at times. I have seen thousands of dead fish along the river but do not remember seeing them above Peoria bridge.

3675 The water between Peoria and Pekin was considerably more dirty. It smelled a little different. The cause of that condition was the offal from the cattle and the sewage from the city. I always considered the river at Copperas creek dam

in the same condition that it was above Peoria. Between Peoria and Henry since the opening of the canal the water seems to be very much improved.

3676 The water in the river opposite the distilleries and glucose factory in front of Peoria is much dirtier than it is above town. That condition disappears before it reaches Kickapoo creek less than two miles. To Pekin it gets better. Below Pekin for a mile or two it is bad and by the time you reach Copperas creek the water is in good condition. The general condition of the water in the Illinois river appears to me to be very much better today than it was before the canal opened.

3677 I have drank the water and know of others who have drank it and do not know of any one getting typhoid fever from drinking it since the opening of the canal. As to the general sanitary condition of the water at present, I take it for granted it is better than it used to be from the absence of smell and color. There are not as many mosquitoes now. The water in the river today could be used in the distillery for the mashing process.

3678 CROSS-EXAMINATION, by Mr. Jeffries:

I will eat anything but the hay my cattle get. There is not now fed more than one-fifth of the cattle per annum that were fed at Peoria several years ago. We consume about

3679 a million bushels of corn at my distillery in a year. The quantity of salt fed to the cattle has not decreased exactly in proportion as the number of cattle has decreased because it takes more salt for cattle eating cotton-seed hulls than it does when they are fed hay. It takes quarter more salt. It appears to me that the water in the river has become void of the impurities discharged into it at Peoria much before the time it reaches Copperas creek dam. That is simply my observation. That was also true prior to the opening of the canal. I don't think there is anything to my knowledge discharged from still houses in Peoria into the Illinois river that is injurious to health.

3680 LOUIS P. BAUER, examined in chief by Judge Johns:

Am Superintendent of the Glucose Sugar Refining Co.,

of Peoria, Illinois. Been superintendent since June, 1898. Works are situated within 500 feet of the shore of the Illinois river in the city of Peoria. On an average 31,000 bushels of corn are used in the manufacture of glucose, per day. (Explains manufacture of glucose.) When the material gets
3682 into the form of starch we use water to wash it. This water then goes into the sewer. The water is almost colorless, a little whitish. It contains a very small percentage of organic matters and traces of sulphuric acid. We use water in the rooms where the starch is separated from the water, for the purpose of washing the floors. This water then goes into the sewer. It has a whitish color. There is no other refuse from our establishment than this water that runs into the sewer.

3683 Use about 6,000,000 gallons of water per day. 1,000,000 from the river and the balance from wells. Before opening of canal we were sometimes embarrassed by a short supply of water from these wells. Since the opening of canal have had no such trouble. I believe the amount of water in these wells varies with the height of the river. Use river water for
3684 steaming purposes. We filter the water before using it for our boilers. Before opening of canal we sometimes used river water without filtering when the filters were out of commission. The unfiltered water caused the boilers to foam. When the boilers were cleaned out a large amount of soft mud was found in the boilers. Have used unfiltered water since opening of canal and there was nothing noticed; no foaming of the boilers. The better water for manufacturing purposes from the Illinois river is that after the opening of the canal.

3685 Of the 6,000,000 gallons of water which we use each day, about the same amount is returned to the river through the sewers. Formerly there was more solid matter discharged into the river through the sewers. The substance was gluten of the corn, more or less starch and slop. The Pekin glucose works does not concentrate its steep water; that is they do now, but they haven't done so until recently. Before concentra-

3686 tion this steep water contains the soluble part of the corn which consists of sugar, gluten and starch. Our factory commenced the concentration of the steep water about 8 years ago. Prior to that time the steep water was discharged into the river. At that time the corn consumption was 12,000 to 15,000 bushels per day.

CROSS-EXAMINATION, by Mr. Jeffries:

3688 Only 10 per cent of the water that goes out of the works has traces of acid in it and that consists of about .001 part of a per cent. You could only notice it by taste—you couldn't see it in the water. The color of the water or matter that runs into the sewers is not clearer than the river water now.

3689 The refuse and other material carried into the river by our factory pollutes the water to a very small extent.

ADOLPH WOOLNER, JR., examined in chief by Mr. Todd:

3690 Am manager of the Woolner Distillery in Peoria. The capacity of the distillery is 7,500 bushels in 24 hours. There has been as high as 40,000 head of cattle fed here in Peoria at one time but I think that is more than seven years ago. They feed in the neighborhood of 10,000 head now. Between 5,000 and 8,000 head are fed in Pekin now. The

3691 cattle are fed about 40 gallons of slop—it weighs in the neighborhood of 10 pounds to a gallon making 400 pounds of slop fed to a steer in 24 hours. They receive besides the slop 10 or 11 pounds of hay and a small amount of salt. Sixty odd ton of urine and feces are discharged from each head of cattle every year. 40,000 times that amount would be 2,400,000 tons. 1,080,000 tons of excreta would come from 18,000 cattle and 600,000 tons from 10,000 cattle. The urine and fecal

3692 discharges from the cattle is run into the Illinois river. That has always been the custom here. The amount of pollution from the cattle-sheds of Peoria from 1887 to the present, has varied from 2,400,000 tons when 40,000 head of cattle were fed to 600,000 tons when 10,000 head of cattle were fed.

I think the water is some better since the opening of the canal, for steam purposes. We had some trouble with foaming before and have had very little since. I do not think that
3693 we had as much current in the river before the canal was opened and the water was sluggish and stagnant and had a bad appearance and considerable color. That section of the river that received the discharge from the distilleries and cattle-sheds before the opening of the canal at low water was in pretty bad shape. There was some smell. The river today I don't think is any worse, if anything some better. I think it is some little clearer than it was before.

CROSS-EXAMINATION, by Mr. Jeffries:

I don't think there were over 10,000 head of cattle fed in Peoria last year. The Atlas has fed 2,500 head for the past nine years—about that. In the future we intend to dry
3694 the slop and export it and use it for domestic purposes. The water is better because the amount of water that is being sent down from the canal gives the river a stronger current which naturally clears the river better than when the river is sluggish; and there is less cattle being fed and will be fed and there is less refuse going into the river.

D. S. BROWN, examined in chief by Judge Johns:

Reside in Peoria. Am in real estate and piano business. Was engaged in distillery business from 1876 to 1886. There were probably ten or twelve distilleries in operation in Peoria during that time. The slops were fed to cattle.
3695 I think there were more cattle fed then than now. During that period the offal from the cattle was run in the river. Those distilleries at that time were located on the river. Prior to opening of canal the Illinois river above Peoria was very bad, very offensive; also at and below Peoria.
3696 It showed the effects of stagnant water and emitted bad odors, and had a bad color. I attributed the condition of the water at that time at and below Peoria to the Chicago sewage. Before opening of the canal below Peoria the water showed the effects of the distillery slop and refuse from the

cattle in addition to the other. It was offensive to the smell. The water below Peoria showed the effects of sewage and had a bad odor. It was a dark brown color. Since opening of canal the water above Peoria has been very good as compared with what it was before, and as I think with other rivers. It is clearer, freer from sewage and has a better color and comparatively little odor. Below Peoria the water is far
3697 better than it was above Peoria before the opening of the canal. I attribute this improvement to the emptying of the clear water from the lake. The opening of the canal has increased the value of lands adjoining and in the vicinity of the Illinois river. It is surer of a cleaner river, a steadier current, better transportation and a healthier river to live by. I considered the Illinois river immediately below Peoria and lands in the immediate vicinity of it, unhealthy before the opening of the canal. I consider the same surroundings healthier since the opening of the canal.

CROSS-EXAMINATION, by Mr. Jeffries:

(Witness is cross examined as to his knowledge of the Chicago river; reasons for constructing the canal and whether all of Chicago sewage has been sent through canal.)

3704 SOLOMON YORK, examined in chief by Judge Johns: Reside in Peoria. My occupation is steamboating. Have been licensed pilot and captain for the last 34 years. In 1852 I came on the Illinois river when four years old. Prior to opening of canal Illinois river above Peoria was bad; no current and stagnant. At times the growth on it would take the wheels off the boat that was running over 25 or 30 revolutions a minute till a kind of whiskers would grow on it. Hair 4 or 5 inches long would grow on the buckets and hull of the boat. The water never foamed above Peoria. Below Peoria the
3705 water was very bad on account of the sewage here; from here to Havana, down as far as Beardstown, you could see the offal from the distilleries here. We worked in front of the distilleries 3 or 4 years digging that out and starting it down the river; it would pile up there 8 or 10 feet deep. Be

low La Grange the water was very bad. It still had traces of Peoria sewage in it below La Grange. Since opening of canal water above Peoria has been better; great deal better current. It is cleaner, purer water; I know it is. Below Peoria it is better; we have 18 to 20 inches more water which makes a current in the river. When you get down to La Grange dam it gets purer. The further you get away from the source of pollution the clearer the water gets and the purer.

CROSS-EXAMINATION, by Mr. Jeffries:

I don't know anything above the sanitary condition of water. What I have said is simply my observation of the river by being upon it.

3706 J. F. VINCENT, examined in chief by Judge Johns:

Live in Peoria. Manager of Peoria Union Stock Yards. Stock yards company owns 22 acres altogether; part is taken up for packing houses, etc. Part that I operate as stock yards is I think seven acres. We drain into the city sewers. An aver-
age of 50 cattle a week pass and have passed through these
3707 stock yards since 1897. These yards are used also for the unloading and feeding of stock in transit. That would average two or three loads a week. We run all the way from 300 to 2,000 hogs a day—an average of 800 hogs a day. Very few sheep. There are two slaughter houses in the
3708 vicinity. One house will kill on an average of 500 a week and the other 600 a week. The sewage from one of these slaughtering houses enters the city sewer and the other one has a private sewer from their place to the river.

CROSS-EXAMINATION, by Mr. Jeffries:

Handle about 100 horses a month. No diseased animals are taken in the yards. If found diseased they are slaughtered and tanked—rendered out for grease purposes.

3710 FREDERICK KINSINGER, examined in chief by Mr. Todd:

Manager of the American Spirits Manufacturing Co. In Peoria three distilleries are connected with that company, the Monarch, the Great Western and the Atlas. Combined capacity of

3 houses is 25,500 bushels a day. We feed cattle only in one of these distilleries and that averages about 4,000 head. One distillery in Pekin is operated by this company and feeds about 3,000 head of cattle at present. These cattle are fed slops from the distillery. The excreta runs into the river.

3711 CROSS-EXAMINATION, by Mr. Jeffries:

I don't know that my company intends to discontinue the feeding of cattle altogether in the still houses here at Peoria.

3713 FRANK C. WHITE, examined in chief by Judge Johns:

Reside in Peoria. Am dealer in live stock. I feed cattle at the distilleries in Peoria. We are feeding at the Atlas Distillery. At present we are getting the slops from the Corning Distillery, but our contract is with the Atlas; when they closed down the last two months we got the slop from Cornings. Have been engaged in live stock business 30 years and cattle feeding business 20 years. For the last two or three years I

3714 have been feeding from 2,500 to 3,000 cattle at one time.

The cattle are fed slop and twice a day the men take a scraper and scrape the urine and manure in the sewer; there is running water in the sewer all the time while they are scraping and probably 3 parts of water to 1 part of sewage. From each head of cattle the chances are there are from 10 to 15 gallons of urine and I don't see how it could be to exceed 6 or 7 pounds of solids. This offal is all washed from the barns into the sewers. We also feed about 8 pounds of hay or cotton

3715 seed hulls per day. Prior to opening of canal this distillery discharge accumulated and was washed off by the high waters into the Illinois river. Some springs it wouldn't have sufficient raise or sufficient water to wash it off and it would remain there during the whole season. There was times when it was a good deal of stagnant slop and manure that accumulated and remained there. We haven't been troubled that way for the last two or three years. Formerly this matter settled in the bottom of the Illinois river and it was dislodged by sending steam boats in to stir it up. It is my im-

ression now that they are forced to do that every year. Salt s also fed. There has been no anthrax in Peoria. I had some xperience with cattle in Omaha that veterinarians claimed had anthrax. I didn't agree with the veterinarians. I
3717 thought it was caused by sewer gas. There was a large smelter just above there and in my opinion the poisonous gases got into the sewers and up into the barn and cattle. They were losing 25 to 35 cattle per day. I had the cattle removed. After the cattle were removed we lost none. Later on they cemented the floor of the barn and they haven't had the same trouble with the barn since. That same season after the ground was froze up we put cattle in there without any cement and took them out in the spring before the ground was thoroughly thawed up and we lost no cattle. This was in Omaha on the Missouri river. The sewage from these barns in which these alleged diseased anthrax cattle were, entered the Missouri river.

3718 CROSS-EXAMINATION, by Mr. Jeffries:

There was I think last year about 11,000 cattle fed against 27,000 to 30,000 fed here ten years ago.

LA SALLE, ILLINOIS, AUGUST 17, 1903.

3719 ROMAN J. RIMMELE, examined in chief by Mr. Todd:

Live at La Salle, Ill. Am a tinner. Reside in La Salle. Have been acquainted with Illinois river 46 years. I run a launch on the river two or three times a week. Run excursion parties up and down the river. Before opening of canal the water used to be very low; dirty looking color; floating grass and weeds all the time; hardly any current at all except in high water; a little odor. Opening of canal in my judg-
3720 ment has improved the water; water looks better; better channel and better water in every way; clearer water. No odor in the water now as I notice. Have about double the current; there was hardly any current before; almost dead water.

CROSS-EXAMINATION, by Mr. Jeffries:

I follow tinner's trade and boat business at the same

3721 time. There is an odor here in the basin all the time but that comes from the sewers here, from the town, in my opinion. The current now is little over double what it used to be. The water is between 2 and 3 feet higher than it used to be.

3722 WALTER A. PANNECK, examined in chief by Mr. Todd:

Am an attorney. Am mayor of La Salle. City has complete sewerage system which empties into the Illinois and Michigan canal. The I. & M. canal empties into the Illinois river about 2,000 feet west of the western limits of the city of La Salle. Population of La Salle is about 14,000; nothing but an imaginary line between La Salle and Peru which has a population of between eight and nine thousand. Peru has about same system of sewerage we have except they empty in Illinois

3723 river below the bluffs. About two-thirds of population of La Salle is connected with the sewers. Excreta from population that does not enter Illinois river through the sewers is hauled by employes of city to bottom lands lying about quarter of a mile south of La Salle. In flood times that land becomes overflowed. The excreta so deposited would get into Illinois river at flood times if it was there. Condition of

3724 public health for last three years has been very good. No typhoid fever at present time. Our water supply comes from Smith's Springs, and Spring Dell Springs and water that comes from I. & M. canal that is driven through gravel and sand to what is known as the intake, three and one-quarter miles east of La Salle and from there it comes by natural gravity into the pumping station and is from there sent out to the city. The connection between this intake and the I. & M. canal is a kind of a small canal with a sand and

3725 gravel bottom to it, and the water coming from the canal just simply flows over the sand and gravel into the lake. It does not flow through it; it travels over it. The water used in the city is made up of a mixture of the spring

waters and the water of the I. & M. canal. This water is used for domestic purposes. The people drink the water. From that water there has not been a case of typhoid fever
3726 since I went into office. Before opening of canal during dry season the Illinois river was very low and stagnant; generally a green scum; practically no flow and the odor was very strong. Since opening of canal it has improved considerably. There is no nauseous smell emanating from the river and there is considerable current to it now. It doesn't get as low as it frequently did and the water is clearer. The
3727 Little Vermilion river enters the Illinois river at this point.

CROSS-EXAMINATION, by Mr. Jeffries:

3729 At the present time we must be using, I would judge, about 500,000 gallons of water per 24 hours out of the I. & M. canal. We are using considerable of that water at the present time. The water comes out of the I. & M. canal through a 12 inch pipe and flows on the surface of the ground immediately south of the embankment, upon the south of the canal. There it travels a distance of probably quarter of a mile through gravel, weeds, shrubbery and such things until it comes to a small lake. The bed of the lake is sand, and below the level of the water is a valve, and a pipe connecting the lake with the intake, and whenever the valve is opened at the lake the water is let in and comes down to the intake by gravity from this lake. The lake is small. I don't know as it
3730 would cover a half an acre. I think we pump in the neighborhood of a million and a half gallons of water per 24 hours in this city. The valve that empties the water from the I. & M. canal into our lake is probably about 97 miles from Chicago. We are 100 miles from Chicago. We
3731 have never spent a dollar upon graveling or filtering that water. It spreads itself or comes all over the surface but must travel a distance of three or four hundred feet around until it gets into this little lake. Since opening of canal the

water in the Illinois river is considerably deeper. The river is deeper and there is considerable more current now than there was.

3732 The water is clearer now than it was. The water that comes into the lake through the valve from the I. & M. canal while it is in the canal at this point appeared muddy, dark. The water from the I. & M. canal mixed with spring water is all right. It is common, ordinary canal water. The people in general say that by itself it is unfit for domestic use, for domestic purposes.

3734 CHARLES H. NICOLET, examined in chief by Judge Johns:

Have lived in La Salle since 1893. Am a civil engineer. Was city engineer of La Salle from 1893 for about four years. La Salle is 60 miles from Joliet by rail.

3735 Water supply for La Salle is drawn from three sources —artesian wells, springs and seepage from I. & M. canal.

La Salle has a system of public waterworks and these three sources of water are received at the same intake. The water is pumped 400 feet from the I. & M. canal until it reaches the intake. I think the so-called springs have their source from the canal and that they are really seepage. The public sewers of La Salle empty into the canal and canal basin and the canal empties into the Illinois river three-eighths of a mile below La Salle. Took samples of water for the State of Illinois in 1899 and 1900 under the direction of Prof. Long. States where samples were taken, method of shipment, etc.

3739 (36 tickets enclosed in an envelope and marked "State of Illinois Exhibit No. 13 for identification, Witness, C. H. Nicolet." 10 tickets marked Exhibit No. 14.)

There are two plants for the manufacture of zinc at La

3740 Salle. I am the civil engineer of the plant. The company which I represent obtains its water from the Little Vermilion river. There is a trace of sulphuric acid in the water that leaves these works and goes into the Vermilion river and

thence into the Illinois above La Salle. This plant uses perhaps a quarter of a milion gallons a day.

3741 CROSS-EXAMINATION, by Mr. Jeffries:

The people do not use the water of the Illinois river for domestic purposes, but it gets into the waterworks system when the water is high from overflows.

3742 The bottoms of the pipes are unsound and the pressure is reversed and the water from the river gets into the pipes and it is drawn into the pumps and circulated. That condition has prevailed this year for about four or five months. The entire city is supplied with that water.

3744 The water that comes from the river during these high stages is not recognized by the people as potable water and all means in the city's power at the present time and heretofore have been used to avoid anything of that kind.

JOHN GRUBB, examined in chief by Mr. Todd:

Am a fisherman.

3745 Before the opening of the canal the Illinois river was kind of stagnated along the shores and slimy stuff would be running along the shores and it would stink. People could not live along there. They would get malarial ague and one thing and another that way and the fish would not be any good along the shore. The only effect I see of the opening of the canal is that fishing has been a little bit better and the fish will live longer in the water and furthermore when I go over there in the spring or fall, I generally take a drink of it. I have not heard of any fishermen who drank the water being made sick on it. There is more fresh water now. Fish live in live boxes and before the opening of the canal they would not live until the next day hardly.

3746 They live now for a week. Before the opening of the canal the fish we used to catch under the ice would taste tarry and gassy. You couldn't eat them. Now the fish have been tasting pretty good. I have drank the water in the river since the opening of the canal eight or ten times a day in the spring or in the fall. It has had no effect on me. It made me

feel like drinking more. Since the opening of the canal I think the river is better for my part and for all the fishermen. They are all catching lots of good fish up there. They catch cat fish, lake perch, a few white fish and all kinds of game fish. There were more pickerel and black bass around this spring than there have been for a good many years.

3747 I never caught lake perch and white fish before the opening of the canal.

CROSS-EXAMINATION, by Mr. Jeffries:

There is a swifter current now and the water is clear. I note that when it rains the water is muddy and that is all. When it is settled, it is as clear as crystal and especially in the fall, last year and the year before.

3748 They claim that the perch came from Lake Michigan through the drainage canal. They never caught them around here before that size. I have caught two or three white fish.

CHARLES RIMMELE, examined in chief by Mr. Todd:

3749 Am in the boating business. Run a small pleasure launch. My father and I run it together. Before the opening of the canal the water had a strong smell to it, full of moss. The water was low, pretty near dead water. Since the opening of the canal the water has been a great deal clearer, no moss, better fishing and no smell. There are more fish than we ever had, and more water. We have got a good deal better current.

3751 W. E. STAFFORD, examined in chief by Mr. Todd:

Have lived at La Salle seven years. Am manager of the Postal Telegraph, also run a boat with Mr. Masterman—the Steamer Creve Cœur. Before the opening of the canal the river did not have the clear appearance that it has had since. It had more grass, gas and stuff of that kind. Sometimes there was an odor. Since the opening of the canal we don't discover it so much. The water has more of a blue cast now. It looks clearer, a great deal. The opening of the canal has raised the water some. The color is clearer than it used to be and the

current has increased. We all drink the water on the boat. It never made me sick.

3752 Have not had typhoid fever.

CROSS-EXAMINATION, by Mr. Jeffries:

City water is not supposed to come from the river. It is supposed to come from springs. I suppose it probably does come from the Illinois and Michigan canal when it overflows from there.

3753 F. L. MASTERMAN, examined in chief by Mr. Todd:

Have lived in La Salle off and on for thirty years. Am agent for the Adams Express Co. Have been on the river a great deal running steam boats. Run the Creve Cœur

3754 with Mr. Stafford. Since the opening of the canal the water is 18 to 24 inches higher. The quality of water in the upper river, where we do the most of our boating is a great deal better—nice clear running water, where it used to be stagnant. There was a natural swamp odor to it. There is no chance for odor on the water now. There is probably in the upper river from four to five mile current. Never experienced any deleterious effects from drinking the water.

3755 C. L. DIESTERWEG, examined in chief by Judge Johns:

Have lived in La Salle forty years. Am a shoe merchant and well acquainted with the Illinois river.

3756 Before the opening of the canal the river was a very dirty foul-odored stream. The opening of the canal has increased the depth of the river from 12 to 18 inches. Since the opening of the canal from observation the water looks to be much better and cleaner. It is a good deal better color. There is a better current and no grass or green scum. There is nothing in the appearance of the water that leads me to believe that Chicago sewage is in the water at this time.

3757 DR. FLOYD CLENDENNIN, examined in chief by Mr. Todd:

Have been practicing medicine in La Salle about thirty years. I think the public health in the city of La Salle since the opening of the canal has been improved. There is very little typhoid fever in the city now.

3758 The condition of the Illinois river before the opening of the canal was bad. It is now decidedly better. The water is purer. The drinking water used here is based on the water from the Illinois river, the I. & M. canal and from some springs and some artesian water. It is a mixture. That water is largely drank by the people. There is very little typhoid fever among the people. I am surprised that there is not more of it, some of the water comes out of the canal and swamps. I had less typhoid to treat last year than I ever had before.

CROSS-EXAMINATION, by Mr. Jeffries:

3759 There are 12 to 14 physicians in La Salle and about five in Peru. I know of my own knowledge that some of the water comes from the Illinois river. The city has not been using every precaution to improve the conditions. They have simply done nothing as I look at it.

3760 The physicians generally advise against the use of the water I think.

3761 AT OTTAWA, ILLINOIS, AUGUST 17, 1903.

W. A. PIKE, examined in chief by Judge Johns:

Have been practicing medicine in Ottawa for seven years. Took samples of water for the State in the Illinois and Fox rivers here, under the direction of Dr. Long. (States where samples were taken, method of shipment, etc.)

3764 Identifies tickets which are marked "State of Illinois, Exhibit No. 15 for identification, Witness, W. A. Pike.)"

3765 The Fox river is a very small stream and enters the Illinois at Ottawa above the main part of the sewage. The samples in the Fox river were taken above the sewage of Ottawa so that neither the samples of the Illinois river water nor of the Fox river water were affected by the sewage of

3766 Ottawa. Before the opening of the canal the Illinois

river was a good stream, except in the summer time. It got pretty low and then there was a great deal of scum and weeds and such things as that floating down the stream or stagnant in it. In low water it had an odor. Since the opening of the canal the current has been greater and the average depth has been greater. There has been a great deal less scum on the surface and the general condition of the river has been much improved.

3767 Ottawa has a source of water supply from artesian wells. The population is nearly 11,000. Sewage is emptied into both the Illinois and Fox rivers.

3768 Since the opening of the canal there has been very little typhoid with the exception of one year which I think was 1901. We had about 20 or 25 cases. Physicians were instructed to have the dejecta of patients disinfected.

3769 CROSS-EXAMINATION, by Mr. Jeffries:

The comparison that I speak of in my direct examination, and prior thereto, is based altogether on my observation of the water.

3774 HENRY MAYO, examined in chief by Judge Johns:

Have lived in Ottawa since 1854. Am an attorney and postmaster. In 1887 was at the head of the Executive and Judiciary Committee for the Illinois Valley Association, which was an organization of people looking into the question of turning the sewage of Chicago into the valley of the Illinois river. I was associate counsel for the special commission appointed by the Governor until the water was turned into the channel of the Des Plaines river.

3776 For five years prior to January, 1900, the upper level of the Illinois and Michigan canal itself supplied the water from the pumping works at Bridgeport. The water lifted by the pumping works into the canal was very largely sewage from the south branch of the Chicago river. It was almost thick. The average amount of water lifted by the pumps at Bridgeport, I think was about 45,000 cubic feet per minute; sometimes more and sometimes perhaps a little less, but the

average amount would be about 45,000 cubic feet of water per minute, about 12,000 cubic feet of water per minute of that amount was required for the purposes of navigation in the Illinois and Michigan canal. The balance, the excess drawn by the pumping works at Bridgeport was spilled into the Des Plaines river where the canal came to the river, and came down through the Des Plaines river from the upper basin of the canal and thence into the Illinois river. The condition of the Des Plaines river at Joliet and down to the Illinois river, while this matter was discharged into it was very offensive. There was a very strong odor from the dams at Joliet, the water was very dark in color and very thoroughly impregnated with sewage. The Des Plaines river entered the Illinois river just above Wilmington and forms the Illinois, by its junction with the Kankakee river.

3777 The Illinois river where it is formed by the junction of these two rivers, prior to the opening of the drainage canal was very much impregnated with the sewage that was taken out of the south branch of the Chicago river by the pumping works at Bridgeport, so much so that the water had a very strong smell—very offensive and was in a bad unhealthy condition. In the vicinity of Ottawa there was a vegetable growth on the water in warm weather and a scum formed upon it. It had a very strong odor, but not so much in the summer as in the winter when the river was frozen over. I live on the south side of the river and cross it two or three times a day and know what I am talking about. I have seen times when it disturbed my meals very much to cross the river before the water was turned in, when the ice was breaking around the piers. The odor was generally most offensive in the winter.

3778 Since the opening of the canal the Des Plaines river at Joliet and down to Wilmington, and the Illinois river from Wilmington to Ottawa, have been, in my judgment, very much improved. The condition of the water both winter and summer has been very much better than it was before. It has not an odor in winter that I have perceived. It has very much

improved in appearance as well. At the Illinois bridge, which is just below the mouth of the Illinois river, there passed 150,000 cubic feet of water per minute and the water in extreme low stage was very offensive, because perhaps one part in six was sewage that came through the pumping works at Bridgeport. That condition has improved vastly since the opening of the canal.

CROSS-EXAMINATION, by Mr. Jeffries:

3780 The people in Ottawa do not use the water from the Illinois river for drinking and domestic purposes that I am aware of. The river is now raised about two feet and the current is a little more rapid than it was before.

3782 CHAS. E. HOOK, examined in chief by Mr. Todd:

Am cashier of the First National Bank and have been mayor of Ottawa for four months.

3783 Have been on the Illinois river more or less all my life, boating and swimming. Prior to the opening of the canal, the condition of the river was bad. It was in such a condition that in the evenings you could not go out in a boat and stand it. It was foul and had a scum on it, but it is much clearer now. The opening of the canal has produced more of a flow and the river appears to be much cleaner and freer from foul odors. The condition of the public health in Ottawa is good. The sewage of Ottawa empties into the Fox river and into the Illinois river.

CROSS-EXAMINATION, by Mr. Jeffries:

3784 I do not know of any one using the water from the Illinois river for drinking or other domestic purposes. As to the condition of the water, I am governed by my personal observation. It is 84 miles from Ottawa to Chicago by the Rock Island road.

M. T. MALONEY, examined in chief by Mr. Todd:

Have practiced law for a living most of my life. I control and own the gas plant in this city, a hotel, an office building and considerable other property. Have been City Attorney,

State's Attorney, Attorney General and Mayor of Ottawa for the last four years. Am acquainted with the Illinois river. Before the opening of the canal from about the middle of June to the end of September, the water was low, foul and filthy. Scum, a greenish plant, permeated all of it right along from one end of it to another. There was little or no current. There was a stench arose from it.

3786 Since the opening of the canal there has been a very vast improvement—that is God's truth—a vast improvement.

3787 Since the opening of the canal my observation is that the water has been free from all of those noxious odors and the accumulation of that stuff on the surface of the water, which of course would indicate a breeding of malaria ordinarily if it continued to exist. I think we are very much benefited. I would say by reason of the accumulation of water that has been coming down here. I think that is the concensus of opinion of all us people throughout this entire valley.

CROSS-EXAMINATION, by Mr. Jeffries:

There is a marked difference in the current of the river.

3788 I think the current carries this decayed matter away. Of course, I don't know just exactly whether it prevents the odor from arising. It certainly prevents that scum that used to form during the summer. The odor is not detected in winter time, as it formerly was.

3790 J. O. LESLIE, examined in chief by Judge Johns:

I reside in Ottawa. Am principal of the High school. Have lived in Ottawa 15 years. Before the opening of the canal the water in the Illinois river was pretty bad, especially in the summer time. You could notice an accumulation of slimy mud and then the water would go off the places where it was not very deep and leave mud on the banks, a dirty stinking mud. That was a regular condition here after a flood and when the waters retired.

3792 The odor was offensive. The current was very sluggish; the water was dirty and full of chunks of stuff. Since

the opening of the canal it has been very much improved. The water stands 20 inches higher and the old muddy banks we used to notice are not exposed any more. You see the white sand and clean gravel that you never used to see before the ditch was turned in.

3793 I cannot see a very great deal of difference in the condition of the health of the children in the schools.

CROSS-EXAMINATION, by Mr. Jeffries:

When I speak of the condition of the water being improved I do so simply from what I have observed. I have never used it for drinking or domestic purposes. I should judge that the current is now at least twice as great as it used to be.

3794 JAMES F. FARRELL, examined in chief by Judge Johns:

Reside at Ottawa. Am a newspaper man and city clerk. There is in the office of the city clerk a record of the deaths from all causes, which has been kept for about 35 years. I am custodian of that record and have the record with me. In 1897 there were five deaths from typhoid fever. In 1898, none. In 1899, two deaths. In 1900, two deaths, in 1901, four deaths. In 1902, one death and none up to the present time in 1903.

CROSS-EXAMINATION, by Mr. Jeffries:

I do not think there is any distinction made between typhoid malaria and typhoid fever. It all comes under the head of typhoid. I have not included deaths caused by pneumonia, where it is stated as typhoid pneumonia.

3795 LESTER J. HORAN, examined in chief by Mr. Todd:

Live at Ottawa, Illinois. Took samples of water for the Sanitary District of Chicago. (States where samples were taken, method employed and method of shipping, etc.)

3801 ALBERT HAHN, examined in chief by Mr. Todd:

Live at Ottawa, Illinois. Took samples of water for the University of Illinois. (States where samples were taken, method employed, manner of shipment, etc.)

3805 DANIEL C. WOODS, examined in chief by Mr. Todd:

Am at present clerk in the Clifton Hotel at Ottawa. I

have done a little work for the Government in the way of reading the gauge on the river for the U. S. Geological Survey. Have been acquainted with the Illinois river forty years. The condition of the Illinois river prior to 1900 in the early days away back, was not so bad. Afterwards it became fouler and fouler until it was very foul. I was engineer on the Chicago & R. I. railroad and that road abandoned their tanks in the station at Joliet and built a coal chute and tanks out about a mile and a half from the station. They also put in filters, but even using the filter the water was so foul that when it was running from the train into the tank, if the wind happened to blow towards the engine it was sickening to the engineer and steam escaping from the gauge cocks or boiler head would sicken you with the foul smell. At Ottawa the smell could be noticed three miles before you reached the town, governed by the direction of the wind.

3807 The water improved as it diffused itself in traveling in the river. Since the opening of the canal there is all the difference in the world. It is now what you would say a clear stream. I see the river every day twice a day at the C. B. & Q. bridge where I go to get my gauges. There is not a particle of slime now any more than any stream you would find in the country that was a clear nice river. The effect of the opening of the canal has been to change the river from a vile stream—a stream that you would know at one glance was vile—that you wouldn't eat a fish out of the river—to a nice clear stream that you would class with any other stream. In fact they are catching lake fish right here at Ottawa.

CROSS-EXAMINATION, by Mr. Jeffries:

There are a great many men and boys fishing at the bridge and I see them catching the same lake perch that I have caught in Chicago myself. I don't drink the Illinois river water.

3810 The current in the river is much more now than it was before the canal was opened. It is forty-five and one-half miles from here to Joliet, which is as far as the river goes.

3811 GUSTAVE KNEUSSL, examined in chief by Judge Johns:

I am a druggist and live within ten yards of the Illinois river. In times of high water part of my premises are overflowed. Prior to the opening of the canal the Illinois river has been covered in summer with mosses and high grass, making it impossible for rowboats to go through. It had a stagnant odor and when the waters receded, there would be a deposit of mud running from one-half an inch to three inches and full of debris. Since the opening of the canal there has been a clear channel. Haven't noticed any moss nor weeds on the shore at all. The current has been greater, much greater. There hasn't been any odor since the opening of the canal. The general condition has been much better since the opening of the canal.

3815 AT MARSEILLES, ILL., AUGUST 18, 1903.

T. W. THIRY, examined in chief by Mr. Todd:

Am a cigar manufacturer. Have lived in Marseilles about eight years. Have visited the river on an average of twice or three times a week during the last eight years. Prior to the opening of the canal the Illinois river was not near as high; had a sort of greenish hue and during the summer would smell bad. The opening of the canal seems to have changed it to a sort of blue, has taken off the scum, made a better flow and it seems to be better and larger. Before the drainage came in, the fish seemed to have a kind of tarry taste, gassy. This year we do not taste it at all. We have now several varieties that we did not have before. We get cisco, lake perch, and pickerel has been plentiful this year.

3817 CROSS-EXAMINATION, by Mr. Jeffries:

The people at Marseilles get their water supply mostly from artesian wells. They do not use water from the Illinois river. The population of Marseilles is about 2,500.

G. W. SMITH, examined in chief by Judge Johns: Reside at Marseilles. Am in furniture business and am an undertaker. Have lived here thirty years.

3818 Prior to the opening of the canal the water in the Illinois

river was very bad. Had a bad odor, smelled like dead animals and had a stinking rotten smell.

3819 It was more disagreeable in winter than in summer. We had flumes here used for running wheels to furnish water power for mills and factories. When the water was frozen over it would pretty nearly make one sick to go into the mill. The gas was so strong it was hard for the men to work in there at times. Since the opening of the canal I consider the water far better than it ever was before. It is clearer and has less color to it—no noticeable odor. It used to have a tendency to foam in the boilers unless the boilers were frequently cleaned.

3820 We have no sewerage system here. The sewage finally goes into the river.

CROSS-EXAMINATION, by Mr. Jeffries:

The people here don't use river water for domestic and drinking purposes.

3821 DONALD A. NICHOLSON, examined in chief by Judge Johns:

Am police magistrate and have resided in Marseilles upwards of 40 years.

3822 Prior to opening of canal the river water was in very bad condition. It had a kind of soapy, gassy appearance on its surface, a dark color, and a green scum would form on top of the water. At one time I had charge of the water power company here. Their works were up on the river above the head gates where the water was kind of still. I have seen green scum form there six or eight inches thick. Since the opening of the canal the water is very much better, clearer and that offensive odor is not there. There is a dam here called the Marseilles dam. The dam when originally built was eight and one-half feet high I think. It is perhaps a little bit higher now—not very much. The Power Company put flash boards on the dam occasionally in low water before the opening of the canal, but not since. These flash boards were 12 inches above the crest of the dam. We have three paper mills, one agricultural

works and two box factories and all the manufacturing that is done here is done by water power. The paper mills run from six to thirty tons each, per day. The liquid from the paper mills would be dark colored, especially where it had been used in cooking straw.

3824 That goes into the river.

3827 JAMES BRUCE, examined in chief by Mr. Todd:

Have lived in Marseilles eight years and am a grain merchant. Have been acquainted with the Illinois river all my life. Prior to the opening of the canal during the summer months, the river was very low. It showed the effect of the drainage of Chicago and the gases from the river were very strong. There were places in the river where it showed stagnant water covered with green slime. Today I think that has all disappeared with the extra head of water and very little gas is found. There has been a general improvement. The river is fairly clean so far as I can see—no stagnant water, and the water has a good flow. At Joliet, my old home, especially between Lockport and Joliet, the operation of the gas showed its effect on the houses there. If you painted a house, inside of a year, it would turn black like my father's place there. Since the canal was opened, we have no such trouble. The game fish are returning up here.

CROSS-EXAMINATION, by Mr. Jeffries:

There is more of a current now than before the opening of the canal. I don't drink the river water.

3829 If there is any gas in the river it ought to show more at the dam and the rapids, than at any other point, because the water is churned up thoroughly there.

3830 W. H. SPENCER, examined in chief by Judge Johns:

I am a grocer and have lived in Marseilles since I was three years old. Before the opening of the canal the Illinois river, when the water would get very low, would have a green scum over it. It would smell very bad and in the winter time when it froze up, the water would churn up in going over the dam and if there happened to be a south wind the stench was almost unbearable at times. That stench was like an outhouse

that the city scavenger would condemn to be cleaned out. Since the opening of the canal I haven't noticed any of those conditions mentioned. The water is much clearer and I have never noticed the smell since. I live about a quarter of a mile from the river. I haven't noticed any odor since the drainage canal was turned in. I noticed it before, any time I would go down to the river when there was a south wind blowing towards town.

CROSS-EXAMINATION, by Mr. Jeffries:

I think the stench was worse when there was no current.

3832 It smelled all times of the year except after a hard rain when there would be lots of fresh water all over the country, which would dilute the water so you wouldn't notice the smell so much. The lower the water got, the worse the smell was. We don't use the water for domestic or drinking purposes.

3833 A. S. GUM, examined in chief by Judge Johns:

I have lived in Marseilles over 60 years. My business is that of teaming. Since the opening of the canal we don't get such a stench from the Illinois river as we used to. The worst we used to get was in the winter when it was frozen over and then dropped over the dam. That was when we would notice it the most. The odor was not as bad in summer as in winter. It was a kind of dark water. A scum formed on it.

3834 Since the opening of the canal I haven't noticed this odor.

CROSS-EXAMINATION, by Mr. Jeffries:

The current is much more rapid now than it was before the canal was opened. The water is pure and more clear than it was before the canal was opened.

3835 H. R. ADAMS, examined in chief by Mr. Todd:

Am Vice President of the Marseilles Mfg. Co. We manufacture agricultural machinery. Have lived here 36 years. We employ from 150 to 250 men. Prior to the opening of the canal, the Illinois river water was very impure, the water of the stream rising from swamps largely. The water was in a very impure condition and before the sewage of Chicago was

turned into the I. & M. canal, we didn't dare to bathe in it for fear of getting mud itch. It was quite a dark, dense color and there was a good deal at times of a kind of formation would come down and the water was not pure enough so that you could see any depth in it.

3836 When the sewage of Chicago was turned into the I. & M. canal there was a bad odor to the Illinois river. If the water was not high, you would see a kind of oily substance on the surface. Just before the opening of the drainage canal, the condition was bad. It had a bad smell and was so intensely filthy that the water from the wheels would saturate the men's clothes and even their systems so that when they would go away from the shops sometimes for days if you went near them you would smell what we called the shop smell of the water. It got very strong. Since the opening of the canal the water has improved very much. During the past year since they have let in some water. I don't know that there has hardly been a time we have had any of that smell. In our head raises, where it used to be so dense you couldn't see any depth, there are often times when you can see two or three feet down clearly. The opening of the drainage canal has effected a very decided improvement on the Illinois river in every way, in health and everything, I think. Prior to the opening of the canal in some parts of the town we used to have quite a little malarial fever, ague and such things as that. Of late, I have not heard anything of that.

3837 CROSS-EXAMINATION, by Mr. Jeffries:

The flow of the current is very much greater now than it was before. It is not very strong at the present time. I haven't noticed any odor in nearly two years, when I have gone through the shop where the water wheels are.

3838 H. B. McKAHIN, examined in chief by Judge Johns:

Am assistant secretary of the Marseilles Mfg. Co. Have resided in Marseilles since 1871. Prior to the opening of the drainage canal during low water stage in the summer time, the Illinois river was very foul, so foul that I had to quit going on

the river much after sundown on account of the malaria. There was a very perceptible odor after the sun left it. In the winter time when the water came through our water wheel at the plant the odor was very foul, very similar to rotten cabbage out
3839 of an old cellar. The odor was so strong that you could smell it on the clothes of the men when they came from the wood shop. Since the opening of the canal I haven't noticed anything of the kind. We don't notice that odor in the winter time nor in the race nor flume of the water power. Before the opening of the canal, a scum formed on the river above the dam and there was considerable growth in the river of vegetable and animal life.

3840 CROSS-EXAMINATION, by Mr. Jeffries:

There is a large volume of water now and a swifter current. So far as I have noticed there is water going over the dam at all times of the year. There is still a slight odor there.

U. T. SMITH, examined in chief by Judge Johns:

I have not any particular business now. I ran a livery stable here for about twenty years and I farmed. I have been here 24 years this fall. Prior to the opening of the canal the river was very offensive and smelled very bad, especially when frozen over. You could hardly endure it. In the summer time, the water would not run over the dam and there would be a green scum and a bad smell. I have never smelled anything since the drainage water has been turned in. The water looks clear and very nice. I haven't noticed this green scum on the water since and I have never seen that dam dry.

CROSS-EXAMINATION, by Mr. Jeffries:

There is more current. The water runs over the dam all the time I think now. I don't drink the water. When I say there is improvement, that is just from my observation.

3842 G. H. SWADER, examined in chief by Mr. Todd:

I live at Marseilles. Am foreman of the Marseilles Mfg. Co. Illinois river water before the canal was opened was pretty bad. There was a kind of a slaughter house smell to it in the summer time, this grass seed and stuff would run down the

river and stop us sometimes at the mill. It would almost hold you up to walk upon it. It had a dirty color to it. The odor made some of the employes sick.

3843 Since the opening of the canal we have more water and it is purer, clearer and better. The water is not drank now. We don't notice that odor. The general condition of the river is better. There is a lot more water running and of course the current is a lot swifter than it was.

CROSS-EXAMINATION, by Mr. Jeffries:

I don't drink the water from the river. I have drank it more or less. I have had to. I don't know anything about what substances are contained in the water.

3844 LEANDER G. DOUGLAS, examined in chief by Mr. Todd:

Am retired farmer and live in Marseilles.

3845 The water in the Illinois river has been decidedly better than it was before the opening of the drainage canal. Before the opening it had a stench, except in extreme flood. At times, it was filthy like. The cattle on my farm up to 1880 had to drink out of the river or out of the canal. In wet times we had what we called sloughs that we watered from.

3846 In my judgment the water is decidedly better in the river than it was before the opening of the canal.

CROSS-EXAMINATION, by Mr. Jeffries:

I don't drink the water from the river. Never use it for domestic purposes.

GILBERT HOWLAND, examined in chief by Judge Johns:

Have lived in Marseilles fifteen years or more. Have lived in the vicinity of the Illinois river for sixty years. Before January, 1900, the Illinois river I considered very bad. It smelled very bad and it seemed down here almost what you might call floating islands. It is a plant or something that grows on the water. I have seen it 18 inches to two feet thick, decaying in the water. There was a terrible odor in the summer. I have not seen a thing of it since the opening of the canal. I have

not seen this scum at all and no odor to amount to anything.

Since the opening of the canal I have caught lake fish here, ciscos and lake perch that I never saw in the river before. I caught any amount of them last season here. It is quite common here to catch lake perch and ciscos here in the river.

CROSS-EXAMINATION, by Mr. Jeffries:

I am on the river pretty much every day. I don't use the water from the river for drinking purposes. There is very little odor now, a larger volume of water and a stronger current.

3849 H. W. COLLIER, examined in chief by Judge Johns:

Have lived in Marseilles and vicinity around here since the spring of 1870. Am now and have been engaged for the last nine years in sprinkling the streets. With the exception of this year we have been getting the water from the canal. Before the opening of the canal the Illinois river at this point was very rotten. You could smell it—seemingly from refuse.

3850 A scum formed on the water like and floating with it. It seemed to be a kind of a slimy gathering. The smell seemed to be worse in the winter. Before the opening of the canal there was objection to using the water because they claimed it was so stinking and it was not fit to be thrown on the streets. Since the opening of the canal, I haven't had any trouble. I never have had any one refuse the water. It certainly has been clearer. There hasn't been one-hundredth part of the odor that there was before.

3851 J. W. VAN LOON, examined in chief by Judge Johns:

Am a painter. Have been in Marseilles 11 years. Have been upon the Illinois river fishing.

3852 Before the opening of the canal the Illinois river was a good deal worse than it is now. In warm weather there was quite a stench to the water. There was a mass of stuff floating in the water. It looked like a kind of jelly that gathered along the shore. The water was very dark oily, greasy and

muddy. Since the opening of the canal we don't see so much odor. The water seems purer. It has the same color as lake water—blue. Don't see any floating stuff and no scum on the surface.

3853 CROSS-EXAMINATION, by Mr. Jeffries:

There is a larger volume of water and a stronger current now.

3855 AT MORRIS, ILLINOIS, AUGUST 18, 1903.

HENRY COOPER, examined in chief by Judge Johns:

I came to Morris in 1866. Am in the harness business. Am acquainted with the condition of the Illinois river during that time.

3856 Prior to 1885, before the sewage was pumped into the I. & M. canal, I did not see anything wrong with the Illinois river, but afterwards it finally got so bad we couldn't catch fish at all. It smelled so bad and they told me it was the sewage that was pumped into the Chicago river. We saw lots of dead fish. There was so much sewage, slime and stuff that came in and it created an odor in the summer.

3857 That condition of affairs continued up to 1900 when the drainage canal was opened. After the canal was opened it began to get better. We have a public water supply here, the water being obtained from artesian wells. We also have one large sewer that runs down the main street and some little branches from it, but that is recent. The sewage empties into the Illinois river.

3858 Since the opening of the canal the water is about five hundred or a thousand per cent better than it used to be. It looks good to me, and it was not fit to be seen before.

CROSS-EXAMINATION, by Mr. Jeffries:

People in town do not use it for domestic and drinking purposes.

3859 There was always some current in the river, and some places where it ran quite fast. It was shallow in some

places and the current was so sluggish that it deposited this stuff along the banks but I never see anything of the kind now. I think there are five thousand people in town.

3860 H. M. FERGUSON, examined in chief by Judge Johns: Am a physician and reside in Morris, Illinois.

3861 I was health officer both before and after the opening of the drainage canal in 1900.

3862 Mortality statistics are reported to the city clerk, but only during the last year. Our mortality here is a little less than 14 per thousand. Formerly typhoid was very prevalent here. Now there is practically none, except imported cases. Since the opening of the canal we have had no typhoid fever except what is imported. I have noticed that and discussed it with the other physicians only last night. We have a paper mill, a foundry, a tannery, a large machine shop, an oatmeal mill and the usual small shops.

3863 The tannery is quite a large one. The refuse from it empties below the bridge into the river.

We have just inaugurated a sewerage system. Before the opening of the canal the Illinois river here was bad. It was murky, ill-smelling, dead and rotten. We could smell it here in town, about a quarter of a mile away. There was a scum on the river and plant life.

3864 This plant was like a clover leaf.

3865 The water in the winter time was very bad. Since the opening of the canal the condition has been better. The water is clearer, less odor and less solids in suspension, and you can see the bottom more. There is a better current. I consider the water since the opening of the canal decidedly better than before. Took samples of water for the State Board of Health, in 1899 and 1900, under the instructions of Dr. Long and Mr. Harman. (States where samples were taken, method pursued and how samples were shipped.)

3869 CROSS-EXAMINATION, by Mr. Jeffries:

The river was very sluggish before the canal was opened.

3871 There is no longer any shore wash. The current is much stronger.

3872 My recollection is that the typhoid fever we had dropped off about the time the city waterworks was instituted, six or seven years ago.

3873 DEWITT C. HOUSTON, examined in chief by Judge Johns:

Am in the grocery business and have lived in Morris continually since 1874. Am acquainted with the Illinois river. Prior to the opening of the canal the water was very bad.

3874 It smelled bad, looked bad and dirty and nasty. It was covered over with green scum in summer along the edges. I have seen places where it was clear across the river. The ice supply here is obtained from the canal. They used to get it from the Mazon creek that comes into the river here opposite the city. Since the opening of the canal the water is a great deal better.

3875 It don't have that bad odor and it don't scum over like it used to. About 1885 was when the fishing quit here. Since the opening of the canal I understand they are catching quite a few fish in the river. We have no professional fishermen here.

CROSS-EXAMINATION, by Mr. Jeffries:

In low water, before opening of the canal, the current in the river was sluggish.

3876 Since the opening of the canal there is a great deal stronger current. I don't drink the water from the Illinois river when I can help it. When I say the water is better I say so simply from my observation. The water looks clearer a good deal.

L. D. RAY, examined in chief by Judge Johns:

I have lived in Morris, Illinois, since 1855. Have been a member of the legislature, in both houses, and Lieutenant-Governor four years. Mazon creek drains the northern part of Livingston and the southern part of Grundy counties.

3878 The DuPage river is quite extensive, with its source up

in Wisconsin. In dry seasons before the opening of the canal the condition of the Illinois river was not good. There have been times when you could be in town and get an odor here which I suppose is from the river. In winter when we were driving on the river, when we came to an air hole, it would be vile.

3879 Since the opening of the canal the condition of the water has been improved. The Illinois river at this point is a considerable body of water at flood season. Nettle creek runs up through the northwestern part of our county. It empties into the river just below the town here.

3880 CHAS. D. FERGUSON, examined in chief by Mr. Todd: Am a blacksmith. Have lived in Morris nearly all the time since 1854. Before the opening of the canal the Illinois river was bad.

3881 I was sheriff six years and have been from the mouth of the river to Ottawa in a boat. Before the opening of the canal the water was inky. It smelled like sewage. Since the opening of the canal the water is not so dark and has not smelled so strong. It smells very little. It is a good deal lighter in color and clearer. I should say that the drainage canal betters the Illinois river.

CROSS-EXAMINATION, by Mr. Jeffries:

I judge from the appearance and nothing else.

3882 G. W. ELERDING, examined in chief by Mr. Todd: Am a photographer and have lived in Morris about 26 years. Have hunted and fished on the Illinois river all my life.

3883 Before the opening of the canal the water in the Illinois river here at Morris was very dark. It was pretty nearly black, kind of an oily appearance, just like grease and it smelled very bad. The farther you went up the river the better it got on the other side. The Illinois river is formed by the junction of the Des Plaines and Kankakee. The water would be better on the Kankakee side. The Des Plaines river would show black on one side and the Kankakee river, white on the other

side. That separation of the waters, if there was a considerable amount of water coming from the Kankakee would extend sometimes farther east than Morris. The general condition of the water at Morris before the opening was bad. It had a bad odor and there weren't any fish to speak of.

3885 The opening of the canal has improved the water. It is clearer, doesn't smell so bad and there are more fish. At times you can detect the presence of sewage from Chicago in the water at this point; it looks a little bit like a sediment of starch floating in the water.

CROSS-EXAMINATION, by Mr. Jeffries:

The current is much more rapid now than it was before the opening of the canal. When I say the water is better, I am judging from its appearance. Two years ago we were camping and we used it to cook with. We drank it in coffee.

HENRY STOCKER, examined in chief by Mr. Todd:

Live in Marseilles. Have been in the boot and shoe business for the last thirty years. Have fished on the river twice a week in the fishing and hunting season for the last ten years. Prior to the opening of the canal the water was pretty rotten and filthy.

3888 It couldn't have been much worse. It had a most disagreeable smell. Since the opening of the canal the water is much clearer. It has lost that odor. The water is much brighter, it isn't so dark and greasy looking. The opening of the drainage canal, in my opinion has been a great benefit to the Illinois river.

CROSS-EXAMINATION, by Mr. Jeffries:

I judge altogether from the appearance of the water. I have drank it since the opening of the canal. There is a good current now.

RE-DIRECT EXAMINATION, by Mr. Todd:

I don't suppose the fish could have lived in that water here. I never heard of anybody catching any. Now they live here. I have seen them.

3890 J. O. LERETTE, examined in chief by Mr. Todd:

Am in the saloon business. Live in Morris. Have been acquainted with the Illinois river through boating, etc. Prior to the opening of the canal the condition of the Illinois river was very bad. Cattle and horses wouldn't hardly drink it. It looked black and smelled a little loud. The opening of the canal has made it a great deal better. It looks better and I do not know that I have noticed any odor since.

CROSS-EXAMINATION, by Mr. Jeffries:

When I say it is better, I say so simply from observation. I have smelled no odor. There is a pretty good volume of water in the river now to what it used to be. There didn't use to be any current in it hardly.

3892 J. C. HARRIE, examined in chief by Mr. Todd:

Am a jeweler and well acquainted with the Illinois river. Cross it every day. Have lived alongside of it for a lifetime. Before the opening of the canal to all appearances the river was bad. We smelled it up town early in the evening. The opening of the canal has had a good effect on the Illinois river. I haven't noticed any smell in the Illinois river since. It is a good deal clearer than it was before and more current.

CROSS-EXAMINATION, by Mr. Jeffries:

I know nothing of the chemical ingredients of the water.

3893 The current is much more rapid than it was before. The people don't use the water from the river. It has a bad reputation among them. Compared with what it was before, the sewage has disappeared altogether from the water in my estimation.

3894 FRED SLACK, examined in chief by Mr. Todd:

3895 Am deputy sheriff in Grundy county. Have fished and hunted on the Illinois river a great deal. Prior to the opening of the canal it was a sluggish stream. The water was stagnant and had a bad color. It was so black at times I could hardly row a boat through it. The opening of the canal has been a benefit to the river at this point. There is much more water flowing through here and the water is clear. I don't ob-

serve the odor. There are fish in the river at the present time. I have caught them out of there. Before the opening of the canal they didn't catch any fish for a long while.

3896 CROSS-EXAMINATION, by Mr. Jeffries:

My opinion as to the condition of the water is based upon observation. They say there is Chicago sewage in the water but I have never seen it. I have an idea there is but I have never been able to find it. Just to look at it you wouldn't think there is any in it. I don't drink the water.

3898 AT ROOM 869, ROOKERY BUILDING, CHICAGO, ILLINOIS, SEPTEMBER 21, 1903.

R. P. ELLIOTT, examined in chief by Mr. Todd:

Am express agent at Wilmington, Illinois. Have been agent since 1866. Took samples of water for the Sanitary District of Chicago. (States where samples were taken, method pursued and manner of shipment.)

3910 JAMES MACK, examined in chief by Mr. Todd:

Collected samples of water for the Sanitary District of Chicago. (States where samples were collected, method pursued and manner of shipment.)

3921 JOSEPH WEIS, examined in chief by Mr. Todd:

Am milk inspector of the city of Chicago. Collected samples of water for the Sanitary District of Chicago, upon the order of Commissioner Reynolds. (States where samples were collected, method pursued and manner of shipment.)

3932 HARRY HUDSON, examined in chief by Mr. Todd:

Took samples of water for Sanitary District. (States where samples were taken, method employed and manner of shipment.)

3938 ARLIE TAYLOR, examined in chief by Mr. Todd:

Am city electrician of Lockport, Illinois. Took samples of water for the University of Illinois, for Prof. Palmer. (States where samples were taken, method pursued and manner of shipment.)

3945 WILLIAM E. O'BRIEN, examined in chief by Mr. Todd:

Am a drayman. Live at Lockport. Took samples of water for the Sanitary District. (States where samples were taken, method employed and manner of shipment.)

3956 T. J. KELLY, examined in chief by Mr. Todd:

Am a dairy inspector. Took samples of water for Sanitary District when Mr. Jos. Weis was taken sick. Took them at the Western Avenue Viaduct. (States method pursued and manner of shipment.)

3962 DR. WM. H. FRASER, examined in chief by Mr. Todd:

Am physician and surgeon. Live at La Salle, Illinois. Have lived there thirty years. Collected samples of water. (States where samples were collected, method pursued and manner of shipment.)

3970 The city of La Salle has a population of probably 12,000. Some of the people have private wells. Most of the people get their water from a spring, or you might call it a series of springs about three miles to the eastward. The water comes those three miles in a vitrified pipe and comes by gravity to the pumping station, and then is pumped of course through the city through mains. When we had dry weather—one

3971 year we had pretty dry weather; I think it was about three or four years ago that we had it very dry and our water supply was short, and it was late in the autumn, the water had been let out of the canal and this stream that runs into the canal about two or three hundred yards to the eastward of this spring, and a pipe was laid from that river called Crozier's creek, and a pipe was laid from that creek through below the canal and it discharged this water into this bed of gravel and that made our supply sufficient for the time. This water of course came from the river, or Crozier's creek, but the pipe got blocked up more or less from debris getting into it, the pipe leading from the river got blocked up so that it would not discharge the water sufficiently and some of the officials went up and punched holes in the bottom of the pipe as it crossed into the bottom of the canal and let canal water in, and so it discharged canal water instead of water from the river.

3972 Q. What proportion of water from the Illinois and Michigan canal entered the water supply of La Salle?

A. Well, there is a pool along the canal on the south side for quite a little distance, besides this pipe that runs out of the canal and the water collects in a large pond or pool, and from that pool there is a pipe laid to the water supply, and it is, I think a six-inch pipe. About one-fourth of the water from La Salle comes from this source. There is no artificial treatment of the water in the Illinois and Michigan canal that enters the supply of La Salle, excepting that which is seeping through the bank of the canal and coming through the pipe that I mentioned, and then it runs into this swampy place and it runs into this pond and then from the pond between the pond and the entrance to the pipe leading to the water supply there is a little bank of gravel which is very coarse and the water rushes right through in quite large streams. You can see it coming through quite distinctly.

3973 I know of only four cases of typhoid fever in the hospital of La Salle and another on Canal street and two in the eastern part of the city. Two of these cases seem to have originated in the city and two came from the outside.

CROSS-EXAMINATION, by Mr. Jeffries:

The water system of La Salle has been in its present condition not more than a year and a half. Of course there was a certain amount of seepage before. This breaking was done by the authorities of the city.

3974 I would not recommend the water for domestic or household purposes.

3977 J. W. MILLER, examined in chief by Mr. Todd:

3978 I live in Joliet and am a guard at the State's prison. Collected samples of water for the Sanitary District of Chicago. (States where samples were collected, method employed and manner of shipment, etc.)

3984 PROF. JOHN H. LONG, examined in chief by Mr. Todd: Am teacher of chemistry at Northwestern University, Chicago. Have been connected with that institution 22 years.

For one year prior to that I taught in the Wesleyan University at Middletown, Conn. Seven years prior to that I was engaged in the study of chemistry. For four years, from 1873 to 1877, in the University of Kansas, and from 1877 to 1880 in the German Universities of Teubingen, Wuerzburg and Breslau. (States societies to which he belongs, names of several books on analytical chemistry, which he has written and states that his work has been mainly in the line of sanitary and medical or physiological chemistry.) Between 1885 and 1890 was chemist of the Board of Health of Chicago. Since 1885 have been chemist of the Illinois State Board of Health and the work which I have done for that Board has been almost wholly in the line of water examination. I have made a special study of water analysis even as a student and in the summer of 1882 I made the first practical examinations.

3986 The first examinations of water that I made in Illinois were in connection with the study of Lake Michigan beginning in 1882. I made numerous tests of the water from the various pumping stations, beginning with Evanston on the north, and Chicago avenue particularly, and later from the Hyde Park station. These first investigations were not official, but were taken up through my general interest in the question of the lake supply. I gave a portion of my time as instructor in the College of Liberal Arts of our institution at Evanston and there became acquainted with the varying conditions of Lake Michigan water, and was led to take up these investigations because of the very general complaints of the character of the water of that place, the supply being drawn from a point pretty near the shore. So, I began at that time rather an extended series of tests, carried on in the laboratory, of my own motion. Later, some tests were made of the water taken at the city inlets I mention, particularly Chicago avenue and Hyde Park. This work was all preliminary to the work taken up by the City Board of Health in 1885. At that time the character of the water had become so altered here that an extended series of in-

estigations was decided on and these were begun and continued for some years.

987 My acquaintance with the Illinois and Michigan canal began as far back as 1883 or 1884—I cannot give that late exactly, but a year or two before the beginning of these egular analyses. The difficulty with the lake water was recogized of course, as depending largely upon the water flowing out from the Chicago river, which in turn depended on the efficiency and flow in the canal; so I gave very early attention to the canal and to the sources of the water going into the canal.

The Illinois and Michigan canal begins in a part of Chicago which is commonly described as Bridgeport. It begins at the pumping station which is very near the corner of Ashland avenue and 31st street, a little north of 31st street and a little east I believe, of Ashland avenue. It runs in a southwesterly direction connecting above Joliet with the Des Plaines river; being led off again it follows down the north bank of the Illinois river to a point below La Salle, where it connects with the river finally. This canal in a general way has been in operation since about 1850 or a little before, and was fed intermittently by pumps from the Chicago river, and to some extent by an old feeder known as the Sag feeder, the water being taken from the Calumet near Blue Island. This canal was so supplied for a good many years, until about 1866, the flow being small. Then it was decided to deepen it, enlarge it, and this was done about 1871, the work was completed about that time, the intention being to produce a gravity flow to carry over 30,000 cubic feet a minute—30,000 to 35,000 cubic feet. This gravity flow began in 1871 and continued until after my examinations began here, so I am familiar with those conditions, and continued until 1883 or 1884. By that time it became so filled with sediment that the flow was extremely uncertain. It very often did 3988 not exceed 10,000 cubic feet a minute, and with variations in the direction of the wind it was probably at times less than that, so that as a matter of fact the Chicago river was practically stagnant in those days. In 1884 as a consequence

of the very general discussion and complaint of the people here, the present system of pumps was established at Bridgeport and these were intended to maintain a flow of fifty or sixty thousand cubic feet a minute. As a matter of fact the flow probably never reached 50,000 during the period in which they were operated. It is altogether likely that the flow did not average above 35,000 or 36,000. I speak of this because I several times went with committees of engineers and city officials to investigate the thing and we never could determine that the flow reached the volume which was claimed for it, so it is safe to say on the average it was much below 40,000 cubic feet all the time.

The Bridgeport Pumping works pumped the water from the south fork of the Chicago river into the canal. The present pumping system was begun in 1884.

3989 A large sewer which is known now as the Brennock sewer was constructed to drain from practically all of the packing houses and to divert and carry the water from those packing houses to the so-called stock yards slip. The amount of filth carried down in that sewer increased enormously for a number of years. Some years after 1871 a contract was given to Mr. John Brennock to take charge of that sewer and see that it was not allowed to clog up. The material was thrown out into the slip, and found its way, a good deal of it, into the river. Mr. Brennock carried that work on for some time as he was directed to do, but later put in a series of settling basins and wiers in the sewer unknown to the stockyards authorities. This is a matter of a great deal of importance as bearing on the amount of stuff which got into the river, so that I ought to explain the facts, as I am familiar with them personally. Mr. Brennock put in these series of settling basins and wiers, which he operated at night. He had a number of men who were employed by him privately, to take out an immense amount of grease and paunch waste, and practically everything which came out of the yards. To begin with, at the start nearly the whole of the stock yards sewage was discharged directly into the slip, but when

s private system was brought into practical operation it took
t the greater part of the solid waste. Later, when that fact
as discovered, the packers themselves undertook to retain this
uff in or near their works by putting in similar systems. This
course would have a very considerable bearing on the amount
stuff that got away from the yards. In the early days very
arly the whole of that got into the slip and occasionally caused
reater pollution than we have ever had since from the yards.
rom the days of Brennock to the present time there has been a
radual modification of the methods followed by the packers in
ischarging the filth into the river, so there has been a gradual
ecrease as shown by the various analyses which have been made
t different times. By these wiers and settling basins it was
ossible, however, to retain only more or less insoluble and
olid substances. Anything which passed into the sewers in a
issolved condition, extracted from the beef—beef extract,
escaped and finally got into the river. The amount of
990 stuff which now escapes is largely of that character
owing to the conditions improving from the days of
Brennock to the present time. Practically the whole of the
olid substances are removed, but when these pumping works
were established that condition was not perfected and the river
was foul very largely from the filth coming down in that way.
Then another item of importance tending to foul the river and
the lake is this: west of the city of Chicago is a small stream,
small in dry weather, known as the Des Plaines river. It drains
a very large area and at times of wet season, at times of high
water, the volume that comes down that river is very large.
Ordinarily the stream flows southwest and enters finally the
Illinois river, but in times of high water instead of taking that
course a very large portion of it always overflows, or always
did overflow, a low watershed west of the city and drained
down into the Chicago river at a point near the Bridgeport
Pumping works. Within my own recollection I have seen
hundreds of acres in the western part of the city flooded from
that stream. Attempts were made on the part of the city to pre-

vent that flow of water, and on the part of the land owners west, to increase the facilities in order to drain their land. As a matter of fact, on a great many occasions the dam at the head of the Ogden ditch, a name which is familar to all of our old citizens of Chicago, was cut by the land owners permitting this flood of waters to go down and flow into the Chicago river and practically wash everything out into the lake. That was the case before 1884 and even after the establishment of the pumps it was frequently the case. When the Des Plaines river overflowed its banks, or the dam was cut, there was a big flood of water coming down and entering there, sweeping everything into the lake. The pumps working at a maximum capacity in those days of 35,000 cubic feet per minute or 50,000 as was claimed, were quite inadequate to direct that flow of water, which, at times, flowed out into Lake Michigan unchecked, causing greater contamination. Those conditions were commonly known and recognized and discussed for several years.

3991 The putting in of the pumping works and the stock yards sewer as far as the amount of filth discharged was of course most important. Further, two large sewers drained the same section of the city, the southern section. One is known as the Halsted street sewer, which empties into the stock yards slip, which is north of the stock yards, approximately at the corner of 39th street and Halsted street, and another is known as the Western avenue sewer, which in those days, however, drained a limited area, but which has since become a very important sewer. At that time another very important sewer was the 39th street sewer which emptied also into the river. All of the west side was drained into the river in those days, and as at the present time, a large part of the south side and a large part of the north side also. Then, as now, in other sections of the north and south side most of the drainage was towards the lake. The sewer at 31st street and the big sewer at 22d street discharged a very large volume of water into the lake.

Practically all of the sewers are gravity sewers. They were in the early days and are yet. Omitting a number of sewers which are pumped—and they are few—practically the whole of the sewage is discharged by gravity and because of the general level condition of the city the flow is very slow and the sewage remains a long time in the sewers. The water pumped into this canal was essentially the sewage of the city. The pumping works were practically adequate to counter-balance the tendency of the river to flow into the lake. In other words, there was practically no current into the lake, so that the water pumped at Bridgeport corresponded to the sewage of the city.

3992 I am acquainted with the history of the public agitation in regard to the contaminated water of Lake Michigan. That acquaintance extends as far back as 1881. Dr. Rauch was for many years secretary of the State Board of Health, and a large part of his interest and activity was given to the subject of drainage of Chicago. He was one of the first of our Illinois men to take up the question of the disposal of the sewage in Chicago in some way and suggestions which he made even before 1880, in the circulars and bulletins of the State Board of Health, were among the first and most important which led finally to a solution of the problem. His recommendations were practically followed in much of the subsequent engineering work. The question of the sanitary condition of Chicago was the subject of very frequent discussion.

Frequently in the meetings of the Chicago Academy of Science, for example, which I always attended, and took part in those discussions. They began even before 1885. This question was also discussed at the time of the first water-way convention, the large water-way convention, which was held in Peoria in 1887. While most of the formal addresses were given on the question of a deep water-way, the discussions in committees and the smaller bodies were very largely on the point of the disposal of the sewage of Chicago. I was a delegate to that

convention and I was taken there at the instigation of Dr. Rauch, to be able to help to discuss that fact.

Dr. Rauch died seven or eight years ago. This general question of the disposal of the sewage of Chicago was discussed also at a very large meeting at Springfield in the following year—1888. A meeting which was attended by health officers and sanitarians and public officials all over the State. The meetings were held at the capitol building.

3993 At that time there was in Chicago a voluntary organization known as the Citizens' Association, which was very active in stirring up discussion on these matters. I was at one time, as early as 1884, employed by this association to make some examinations of the sewage coming from the stockyards and other points near the Bridgeport pumps. This association was perhaps a most important factor in crystalizing sentiment in favor of the commission which was later established, known as the Hering Commission. There was a meeting called at Peoria in 1887 by the people interested in the question of a deep waterway from Chicago to the Mississippi river. That convention was made up of delegates from all parts of the State of Illinois and adjacent states and cities. There were delegates at that convention from the State of Missouri and the City of St. Louis. Personally, I remember the name of Mr. McMath.

3994 I met at that time delegates from a number of cities who were particularly interested in the question of sewage rather than the question of waterways, as I said a little while ago, that question was, among many of these men, a prominent feature of the discussion. It was recognized that the construction of a waterway canal involved the disposition of the sewage of Chicago, so that that feature of the question received the greatest publicity in the discussion.

There were four or five other delegates from Missouri. Mr. McMath is an engineer of the city of St. Louis, who has had a great deal to do with water and sewerage systems of that place and of considerable reputation, and his name has been known in connection with this work for years. The proceedings of that

convention were given publicity in the public press. The matter was discussed in the St. Louis papers at that time. The Hering Commission was established as a result of this agitation for the improvement of the water supply of Chicago and the diversion of the sewage; agitation kept up for a number of years. It was established in 1886 or appointed at that time. It began work and continued through 1887 I believe.

3995 The lake water at that time, at periods of dry weather, was in general, fairly good. At the time of rain, however, when the discharge from the sewers into the lake was considerable and when the flow through the river was out instead of in, the water became, at the various pumping stations, more or less contaminated, noticeably contaminated. The river for that period was practically always bad and foul.

Q. Did you make any series of investigations of the water of the Illinois river, its tributaries, the Illinois and Michigan canal, Lake Michigan, and the Chicago river, prior to the opening of the drainage canal in 1900?

A. Yes, I made made several series of those investigations. The first investigations were on the lake water to determine the fact of its increasing pollution, the water being taken from the Chicago avenue tunnel and from the Evanston and Lakeview tunnels, and from the Hyde Park tunnel, the two longer tunnels not having been built at that time. The waters were taken from faucets connected with the city mains, and were also taken by myself from the lake direct, at various times, to determine the general condition of the water at various distances from the shore, the object of all these investigations being to learn the facts of the condition of the lake with reference to increasing pollution. This work was done prior to any work which I took up on the Illinois river and canal.

The first investigation included the examination of a great many samples of water from these stations that I have men-

tioned, weekly examinations carried on through a period of several months at each one of the stations.

3996 The next examinations were concerned with the river and canal water, beginning at Bridgeport. That first series of investigations was started in 1886. That comprised a study of the water samples taken weekly at a number of points beginning at Bridgeport and continuing down the river to Peoria. It comprised examinations from Bridgeport, Lockport, Joliet, Ottawa and La Salle, to Peoria. The average number of samples analyzed at each of those points as I now recall it was about 12. They were not quite all the same number in 1886, between the beginning of the investigation and the early summer and fall. I have all the dates but I don't recall them. I didn't think they were essential. I have in memoranda and reports the results of those analyses. They were published in the reports of the Illinois State Board of Health. Following this first series in the summer and fall of 1886 I began a second series of experiments in the winter of 1886 and 1887, taking the colder months, beginning about the first of January, the end of December, 1886, to the first of January, 1887, and this

3997 series was continued through two or three months into March. These investigations were carried out at the same points between Bridgeport and Peoria. A smaller number of samples of water were analyzed than through the summer, as the period of investigation was shorter. The result of these investigations were published in the same reports of the Illinois State Board of Health. I am the John H. Long referred to in the testimony of different witnesses for the State of Missouri, having made the reports referred to by these witnesses. The next investigations were made two years later beginning in 1888. I will give the exact dates on that. The summer of 1888, beginning with May 1st and continuing into the fall and ending about the middle of November, I made along the river 650 chemical examinations, beginning with Bridgeport and including the same places included in the previous examination,

but continuing below Peoria to the mouth of the river at Grafton.

3998 In 1888, during the period mentioned, May to the middle of November, samples were taken from Bridgeport, and Lockport, Joliet, Morris, Ottawa, La Salle, Henry, Peoria and Pekin, near the mouth of Copperas creek in the Illinois river, Havana, Beardstown, near Pearl at the crossing of the Chicago & Alton railway, the Alton bridge as we call it, and Grafton. In that same investigation waters were taken from a number of the tributaries of the Illinois; from Du Page river which enters from the north from below Joliet; from the Kankakee river which enters from the south still farther down; from the Fox river which enters just above Ottawa; from the Big Vermilion river which enters from the south near La Salle, or a little above La Salle; from the Little Vermilion river which enters from the north near La Salle and from the Sangamon river which enters across from the town of Browning; enters from the opposite side of the river from Browning. Those were tributaries of the Illinois.

The results of this investigation were published in the preliminary report of the State Board of Health printed in 1889.

This preliminary report was brought out by the Secretary of the State Board of Health for the use of some committee of the Springfield legislature in a very great hurry. The work of printing the report was begun but a few days after the completion of the last analyses, so that the work must be regarded only as of a preliminary character, and while the details were complete, the text and explanatory matter was comparatively meagre. The full report which was put in the hands of the secretary, in some way was lost and was never printed. The details are substantially completed here, but the report itself is not. That explanation is due the secretary of the State Board of Health, Dr. Rauch, and myself, to account for the peculiar character of this work. It was brought out in two or three days very hastily.

3999 The detailed analyses published in that report are es-

sentially correct as far as I could read the proof and correct the figures in two or three days. The averages are practically all correct. This investigation I have described was made in the late spring and summer and fall of 1888 and that was followed in the winter of 1888 and 1889 by another investigation, and the waters were collected at essentially the same points to determine the winter conditions of the river. I should have included them as one series. 96 samples of water were analyzed in this investigation and the results published in the same report of the Illinois State Board of Health printed in 1889. The details and averages as published in that report are essentially correct.

4000 (Witness states how the samples through the series of 1886, 1887, 1888, 1889, 1890 and 1891 were collected and shipped.) The next investigation was made in Chicago of the water in the neighborhood of Bridgeport pumps, in the winter of 1890 and 1891.

The object of that investigation was to show the relative amounts of pollution coming from the stock yards and from the rest of the city. Therefore, samples were taken at points which would best show that. They were taken from the large sewers leading from the stock yards, and from the so-called Brennock sewer which I spoke of a little while ago, which enters the stock yards slip, very near Center street, practically at Center street; from the Ashland avenue sewer which enters the south branch of this south fork some distance west of the stock yards slip, and from the Halsted street sewer which enters the slip at Halsted street just mentioned. Water was also taken from the 39th street sewer, and from a point north of where the water is diverted from the main river, going to the Bridgeport pumps. Samples were marked "Main street;" I cannot describe it more closely, but these samples included the bulk of the sewage, or represented the bulk of the sewage outside of the stock yards sewage.

4001 The purpose of these analyses was to show the effect of the discharge of the sewage from Chicago on the Illinois

river. The analysis made of those waters was a so-called sanitary analysis, which embraced the determination of certain factors, which are considered as important in showing the sanitary character of water. This included the determination of total solids, suspended matter, nitrates or nitrogen in nitrates and chlorine.

4003 (Describes the difference between the old and new method of determining chlorine.) I have used in preference to the old method the Volhard method.

4004 I also determined the so-called hardness of the water, free ammonia, albuminoid ammonia also oxygen consumed. (Witness states method by which these determinations were made. Witness states how these results obtained by chemical analyses are interpreted by the chemist and their significance with reference to water.)

4012 JOHN E. THOME, examined in chief by Mr. Todd:

Am mechanical engineer, at Washington Heights Pumping Station. Collected samples of water for Sanitary District, at the discharge of the Canal Pumping Station, about 300 feet west of the canal station probably. One sample to go to Chicago University, one to laboratory at city hall and one to Champaign. (States method pursued, etc.)

4018 PATRICK O'BRIEN, examined in chief by Mr. Todd:

Live at Lockport, Ill. Collected water for Sanitary District of Chicago and State of Illinois in 1899, 1900 and 1901, from I. and M. Canal and Des Plaines river. (States method pursued and places where water is taken.)

4026 PROF. JOHN H. LONG, resumed stand for further direct examination by Mr. Todd:

If chlorine is found in water in large amounts, above the amount found in waters of a region known to be uncontaminated, it is taken as an indication of a possible addition to the water of sewage in some form at some time. If chlorine is found in water and these other nitrogenous compounds of which I spoke are absent it is simply a suggestion that possibly the water has received sewage of some kind Not necessarily sew-

age because the water may have received drainage from a salt mine or well—so I say it is a suggestion of the possible addition. I have in this report of the proceedings of the Illinois State Board of Health, the quarterly meeting at Chicago, October 28 and 29, 1886, a table of results of examinations made at that time. I have a table of averages drawn from those results. In this table of averages that I have here, there were but three determinations made in that year, 1886, free ammonia, albuminoid ammonia and the oxygen consumption. This table I have in two different forms. In the first report the average of all the

analyses was given. In the second, published along with

4028 this preliminary report as it is called, there is a table

calculated from the individual experiments, leaving out certain ones, however, in order to include the sample taken in the same day. For instance, in the first table there are ten analyses at Bridgeport and only 7 at Peoria. In calculating this table the averages are based on the same number of samples throughout. Therefore the fairer table to use would be this.

MR. JEFFRIES: I object to the reading of the averages for the reason no evidence shows samples were properly taken, etc.

Results given are in parts per million.

(Witness reads results for Bridgeport, Lockport and

4029 Joliet, Ottawa and Peoria.)

That is taken from page XXVII of preliminary report of Illinois State Board of Health, published in 1889, by the authority of the State Board of Health. These analyses show beyond any question a very marked destruction of organic matter in the flow between Bridgeport and Peoria, showing the effect of what is called bacterial oxidation in an extremely marked degree, the water at Peoria in that particular season being practically potable and actually used by a large number of people. I was at Peoria during the season and observed that fact myself. That was in the summer of 1886. This effect is partly of course due to the oxidation and also to the dilution from tributaries, but the largest part of the effect is unques-

tionably due to actual destruction by bacterial oxidation.

030 The summary for the winter of 1886 and 1887 is for four places, Bridgeport, Joliet, Ottawa and Peoria and is aken from page XXIX of the same report. (Objected to by Mr. Jeffries.) Summaries read.

031 The conclusion I draw from these averages is that in the winter of 1886-7 as in the summer of 1886, there is a ery considerable destruction of organic matter in this stretch etween Bridgeport and Peoria, but the destruction or oxida- ion is much less marked and characteristic than in the summer, s is always the case in these observations.

The summary for 1888 will be found in same report, page 30. I made that table of the analytical details which I made at the time of the analyses.

(Witness gives pages of report from which summary is made for various towns.)

4032 MR. TODD: I offer the tables appearing on those pages as State of Illinois, Exhibit A for Identification.

(Objected to by Mr. Jeffries.)

4033 I have the summary made by me from those tables of analyses which are known as State of Illinois Exhibit A for identification.

(Witness reads into record table entitled, "Means of Analyses, May to October, inclusive, 1888." Results are expressed in parts per million. Also table entitled, "Means of Analyses during 1889." These tables follow each other as follows: Bridgeport, Lockport. (4033.)

4034 Joliet, Morris, LaSalle, Henry.

4035 Peoria, Pekin, Havana.

4036 Beardstown, Grafton, Alton. Table No. 2, Bridgeport,

4037 Lockport, Joliet, Joliet, (Dam 2) Morris.

4038 La Salle, Henry, Peoria, (Upper Bridge), Pekin.

4039 Havana, Beardstown, Grafton and Alton, (4040.)

These results show a purification of the river between the source of the water at Bridgeport and the outlet of the

Illinois river at Grafton. The purification measured by the destruction of organic matter, showed a very great or a very marked diminution of the organic matter. This diminution of the organic matter is due to two principal factors—the dilution of the stream by the water from various tributaries, and to the destruction of the organic matters by the oxidation, using that term in a general sense, or broad sense. The disappearance of organic matter is very much more marked than is the dilution, as indicated by the change in chlorines, the condition being finally reached in which the organic matters are not larger or greater in amount than in the tributary streams.

(Objected to by Mr. Jeffries.)

And are not larger in amount than in the streams commonly found in that part of the country.

4041 I made in connection with this investigation an analysis of the waters of the tributaries of the Illinois river; the DuPage, Kankakee, Fox, Big Vermilion, Little Vermilion and Sangamon rivers. That is all bearing on that.

4042 (States where samples for this purpose were collected and the manner, etc.) I have the table of analyses made by me from these samples for the DuPage river. That table is found on page 14 of this preliminary report of John H. Rauch.

4043 Table read as Table No. 3, showing results at Channahan, Du Page river, for period from May 4 to September 21.

4049 I have table of analyses made of the Kankakee river and it will be found on page 15 of this same report, (Arabic notation.) (Objected to.)

4050 Table read in record as Table No. 4, Wilmington, Kankakee river, for same period.

4056 Table for Fox river will be found on page 17 of said report; for Big Vermilion on page 18; Little Vermilion on page 18 and for Sangamon river on page 26.

Table No. 5, being Ottawa on Fox river, read in record.

4063 Table No. 7, being LaSalle on Little Vermilion.

065 Table No. 6, being La Salle, Big Vermilion.

068 Table No. 8, being Chandlerville, Sangamon river.

(Objection by Mr. Jeffries to reading tables and to making conclusions therefrom.)

072 The consideration of these tables which have been referred to and given by me, and the comparison of the results of the analyses of the Illinois river at its mouth, with the results of the analyses of the tributaries of the Illinois, indicate that a condition of organic purification of the Illinois at its mouth has been reached, which is comparable with or similar to that found in the tributaries mentioned. As indicated by the various tests which have been described, the organic matters in the Illinois river have been reduced to a point where they are not larger in general than the organic matters found in the several tributaries. They have been reduced to a point beyond which the destruction of organic matter in the river by natural means can not practically be exceeded or surpassed. Apparently the limit of oxidation of the organic matters has been reached. We have here a condition in which the organic matters have been broken down and destroyed largely, and the residues that are left, not destroyed, are of a stable type, very resistent to all oxidizing influences. A condition characteristic of organic matter of vegetable rather than animal origin, from which I conclude that in general these organic matters must be attributed to the leechings of the soil, that is to products of vegetable origin rather than to the products of animal origin. This condition obtains in all the rivers to some extent and in the Illinois river at its mouth and its tributaries.

Objection by Mr. Jeffries.

4073 The organic matter in the Illinois river at points far above its mouth, is in general larger than the organic matter in most of its tributaries, but by the time the mouth of the river has been reached, the organic matter has become so far reduced that it compares in general very closely with that found in the tributaries, and does not exceed that in the tributaries in general. In most of the examinations the condition of the water

at Upper Peoria or Averyville, as it is sometimes called, is very analagous to that of tributaries. There is a purification of the organic matter there so that the water corresponds closely to the water of the tributaries. These answers are all directed to the period of these examinations. The water of the Illinois river at Grafton in this season, in the summer of 1888, has reached a degree of organic purity fully equal to the mean condition of the waters in the tributaries mentioned, the DuPage, the Kankakee, the Fox, the Big and Little Vermilion and the Sangamon. In drawing these conclusions I have taken into consideration essentially these three factors, the amount of free ammonia, the amount of albuminoid ammonia and the figure repre-

4074 senting the oxygen consumption. I have also considered the condition of oxidation as shown by the amount of nitrates, nitrogen in nitrates. There are four elements in reality going to make up this conclusion and by comparison of these four elements, it has been shown that the Illinois river has reached a condition of organic purity comparable with the tributaries. (Witness gives a comparison of averages of chemical elements from which he has formulated his opinion, for the tributaries of the Illinois and at the mouth of the Illinois river.)

4075 The average of all of these results from all of the rivers will show a condition of organic impurity as great as that of the Illinois at its mouth. (Witness explains reasons for his belief.) Am acquainted with the Illinois river and its tributaries from personal knowledge by actual observation at various times. Have personal knowledge of the sources of sewage contamination entering the Illinois river and its tributaries from an examination of many points along said river and its tributaries.

4078 I have the table of analyses made by me in the winter of 1888 and 1889. I made examinations in the winter of 1888 and 1889 of 8 or 9 samples from Bridgeport, Lockport,

Joliet, Morris, LaSalle, Henry, Peoria, Pekin, Havana, Beardstown, Grafton and Alton. The table of analyses appears in the State of Illinois Exhibit A for identification. The summary made by me from these tables of analyses is in this preliminary report, page 30 with Roman notation. That is the table
4079 that was read into the record yesterday by me, immediately following the table on same page of report from May to October, inclusive, 1888.

Objection by Mr. Jeffries to witness giving conclusions for reasons stated in objection.

This table giving the summary of the analyses made during the winter of 1888 and 1889, shows a considerable reduction of organic contamination of the water between Bridgeport and Grafton, but a very much less marked degree of reduction than was observed in the summer of 1888. This difference is particularly noticeable in the factor for the oxygen consumption, and for the albuminoid ammonia, and it is also shown by the factor expressing the amount of the free or saline ammonia present. One of the most important points in this table is found in the figures showing the amount of free ammonia, albuminoid ammonia, and the extent of oxygen consumption at Pekin during the winter. While in the summer work the amount of organic matter in the river at Pekin as disclosed by the analyses does not appear to be excessive, at any rate no very great increase is detected there, during the winter of 1888-9, these factors show, especially as regards the undecomposed nitrogenous substances indicated by the albuminoid ammonia, a very large residuant. The condition indicated by the figures for oxygen consumption is also one of increased organic contamination. The explanation of this is not difficult and should be given here.

4080 During the summer season in the stretch between Peoria and Pekin, which is a nearly level stretch of eight or ten miles in extent, an enormous decomposition of organic matter occurs, as is observable in passing through the stream. This decomposition is a bacterial or fermentative decomposition, as

disclosed by the rapid evolution of gases in this part of the stream, so that roughly, this stretch may be compared to a great septic tank in which hundreds of tons of organic matter are undergoing decomposition all the time. The rate of decomposition of organic matter varies as is well known, by temperature. In the winter season therefore, we have this rate very much slower, so that at Pekin, below the distilleries and cattle sheds of Peoria, the enormous pollution as indicated by the residual albuminoid ammonia factor and the factor for oxygen consumption indicates fresh and recent additions. The consideration of these figures shows beyond question whatever, that the addition of filth at Peoria is a very important factor in accounting for the organic matter in the river below. I am confining my answer to the period of 1888 and 1889, and not to a date subsequent to that time.

4081 Another feature which must be referred to here is the high free and albuminoid ammonia as disclosed at Grafton, and the high oxygen consumption also. This summary is made from the average of results given on page 28 Arabic notation, of the body of the report, and the individual examinations there show very great and considerable variations.

In the last of the examinations made in March of 1889, for some reason which I cannot explain now, the factors for free ammonia, albuminoid ammonia and oxygen consumption, were unusually high. The addition of these in making up the general average, as given on page 30, Roman notation, accounts for the relatively high figures given opposite Grafton—figures relatively higher than those given for the next town above, Beardstown. It is evident from a consideration the figures on page 28, Arabic notation, of the report, that at that time the river must have received at that point a very greatly increased contamination, possibly from the breaking up of ice and the washing down of accumulated filth. I have no data to show at the present moment how that could be accounted for. So, in resume, in consideration of this table, while in general a reduction of organic mat-

ter appears during the colder season, it is markedly less than during the warmer summer weather before.

4082 I had personal knowledge as to the condition of the sewage of Peoria during this period from trips down the river at that time. I made several trips to Peoria during the period of these examinations, and between Peoria and Pekin. I have read the testimony given by witnesses in this case at Peoria, in regard to sewage. I have read the testimony given by Dr. Keiser and Dr. Teichman in their analyses.

I have not with me the table of analyses for winter of 1890 and 1891. Those analyses were of the sewer waters discharged near Bridgeport, and were not published. I have a resume of these summaries in report form. It is found in the report of the Illinois State Board of Health published in 1901, p. 67.

4083 JAMES M. QUINLAN, examined in chief by Mr. Todd:

Am clerk in Law Department of Sanitary District of Chicago. Took samples of water from Kaw and Missouri rivers. (States where samples were taken, etc.)

4087 I investigated the sewage out-falls of Kansas City, Mo. The sewers all emptied into the Missouri river above the place where we took this water. That is, there are two or three —but we took the samples about a mile above where they entered and then below where they all entered. There are four large sewers empty into the Missouri from Kansas City. I saw them.

CROSS-EXAMINATION, by Mr. Jeffries:

4088 I know that there are four sewers. There may be smaller ones, but I know of my own personal knowledge that there are four. There may be more.

4089 I know what proportion of the sewage empties into cesspools. I can say that five-sixths of the sewage empties into the Missouri.

4091 FRANK C. BURKE, examined in chief by Mr. Todd:

Am in teaming business at present time. Went to Kansas City with Mr. Quinlan.

4092 Took samples of water from the Kaw and Missouri rivers. We investigated the different sewers that emptied into the Missouri river as far as we could do so.

4094 We found four large sewers emptying into the Missouri.

4095 PROF. JOHN H. LONG, resumed stand for further direct examination by Mr. Todd:

I made on several occasions, examinations of the sewers in the neighborhood of Bridgeport and south of Bridgeport, first in 1888 and later in 1890 and 1891. The winter of 1890 and 1891, I made more extended investigations to determine, if possible, the proportions of organic matter discharged from the sewers of the city and from the stock yards, and the amount of this which passed the pumps at Bridgeport. The 1886 investigation was made for Citizen's Association and was concerned mainly with what I spoke of yesterday, as the large Brennock sewer, carrying the bulk of the stock yards sewage at that time. The amount determined then was equivalent to about 112 tons daily of dry, organic matter. I made altogether about 130 examinations in 1890-1891.

4096 The figures I quote from were made when I had those averages in my possession some years ago. They have been mislaid since. These figures are important as showing as accurately as I could determine at that time, the amounts of organic matter. The facts which I am about to detail I know of my own personal knowledge to be correct. These facts were obtained by me in the analyses of samples of sewer water collected in the winter of 1890-01. The original analyses I still have, but the memoranda which I have not are memoranda of flow in the sewers, which would be necessary to calculate the amount for 24 hours, but before these memoranda were mislaid, the statement I have here was made and I vouch for the correctness of that statement. The statement was made by me.

4097 I found at that time that the organic matter which was discharged from the city and stock yards sewers in the neighborhood of the Bridgeport pumps amounted to approxi-

mately 240 tons daily. (States method of arriving at this conclusion.) The figure that I have given here of 240 tons is the amount discharged from the sewers. The next important question was what portion of this actually passed the pumps into the canal. It was found that about five-sixths of the water in one series of investigations, the one which I have given, passed the pumps at Bridgeport. The decomposition of the remainder of the organic matter was in the city. In the warmer months a very much larger proportion of the organic matter is decomposed in the city than in the colder months. The last examinations I have testified to were not made a matter of publicity. The first ones made in 1886 were. The last ones were not published except in this book. The only publications made were in the resume which I have quoted from, pp. 67 and 68 of report of State Board of Health, printed in 1901.

4098

4099 The comparison of the results obtained in the Illinois river in 1886, with those obtained two years later, 1888-1889, indicate increased pollution of the Illinois river at Peoria. From personal observation of the Illinois river at Peoria in 1886, I know that the water was potable, and formed a large part of the water supply of Peoria. From personal observation I know that later this water supply was abandoned because of the increasing pollution of the river, which was shown also by the analyses. For 1886 the point farthest down the

4100 river for which I have analyses is Peoria.

Am acquainted with the facts that led to the appointment of the Hering Commission. As chemist of Health Department of Chicago and chemist of State Board of Health, I was familiar with the discussion regarding the water supply of Chicago and the increasing pollution of the same. A commission consisting of Rudolph Hering, an engineer, as chairman, and Benzette Williams, and the city engineer, Mr. Actingstall were appointed in 1886. This commission after considering various plans (enumerated in the testimony) decided in constructing the so-called drainage canal, following essentially the recom-

mendations which had been made by Dr. Rauch of the State Board of Health, and others, years before.

4102 The recommendations of Dr. Rauch were frequently published in various bulletins from the State Board of Health and the proceedings of sanitary conventions and elsewhere. The recommendations of Dr. Rauch were made in 1879 and published in the preliminary report of the Illinois State Board of Health of the water supplies of Illinois and the pollution of its streams, printed in 1889 by the Illinois State Board of Health by Dr. Rauch. This report was published in 1889 for the purpose of giving the results of examinations of the water in the lake and Illinois river made by myself for the Illinois State Board of Health. At that time the legislature was in session.

4103 This report was gotten out in answer to questions brought up in Springfield regarding the character of the water of the Illinois river and the changes in the water by flow from the sewage from Chicago through the canal, the Des Plaines river and the Illinois to Peoria and the towns below. These questions emanated in the legislature at Springfield. It was called a preliminary report because it had to be got out in a hurry. As an actual fact the full report was made by me later, but it was not published.

I made a series of analyses in the year 1899.

4104 In the summer of 1899 I was authorized by the State Board of Health to begin a chemical examination of the waters of the Illinois river and its tributaries and the canal leading from Chicago into the Illinois river. Before beginning those analyses I made a trip of inspection from Bridgeport through the canal and down the Illinois river to the mouth of the river at Grafton. This trip was made in company with Mr. Jacob A. Harman, an engineer employed by the State Board of Health, and was for the purpose of familiarizing us with the locations and general conditions along the river and for the further purpose of selecting water takers to obtain samples of water for the various points and ship them to me

at Chicago for examination. The points selected were Bridgeport at the source of the Illinois and Michigan canal near Ashland avenue and 31st street, Chicago; Illinois and Michigan canal at Lockport; Des Plaines river at Lockport; Joliet,
4105 being the water of the canal and Des Plaines mixed;
4106 Morris; Ottawa; La Salle; Henry; immediately above Peoria at the part of the river described as the Narrows and sometimes called Averyville; below Peoria, the point being described as Lower Peoria, or sometimes as Wesley; Pekin, below the outlet from the cattle sheds of the distilleries, being about two miles below Pekin bridge; and Havana, above the mouth of the Spoon river; at Pearl, and at Grafton.
4107 A number of samples were also taken from the tributaries of the river. The first is Kankakee river below the town of Wilmington; from the Fox river above the Rock Island bridge; from the Big Vermilion river at a point about two miles above La Salle; from Spoon river several hundred feet above its junction with the Illinois; the Sangamon river near its mouth, at a place called Browning; the Mississi-
4108 sippi at Grafton, being above the mouth of the Illinois. Also some head water samples from the Kankakee river near South Bend, Ind.; the upper Des Plaines near Libertyville; the upper Du Page near Wheaton; the upper waters of the Big Vermilion at Pontiac; from the Mackinaw at the town of Kappa; the upper Sangamon at Mahomet; the upper Spoon at Dahinda. Those are all the places from which samples of water were taken for investigation in 1899. (Witness also gives names of collectors taking the above samples.)

In 1900 samples were collected at the same points as during 1899, with the exception that samples were taken in 1900 from the now opened drainage canal at the Western avenue bridge and also from the basin of the canal at Lockport.
4109 In 1901 samples were collected at the mouth of the

Illinois river at Grafton; the Mississippi at Grafton; from the mouth of the Missouri at a point about 200 yards above its junction with the Mississippi. Those were the only places where samples were collected in 1901.

4110 The collectors who took these samples were selected by myself mostly. (States directions that were given to collectors. States how samples were received at the

4114 laboratory.) When these samples were brought to the laboratory the analyses were undertaken at the earliest possible moment and always the same day. The samples from each particular point had a serial number and were labeled with a card in an envelope.

4116 These cards are marked "Defendant's Exhibit No. 4."

4119 In the first investigation of 1899 the samples of water were collected for most of these places weekly, the dates of collection being given in the Illinois State Board of Health report published in 1901. The samples were collected in 1900 from the same places also weekly. In 1901 samples were collected weekly or in some cases more frequently. These samples that were received at the laboratory—each card represents one chemical and one bacteriological sample. After the arrival of the bacteriological sample at the laboratory certain tests of a chemical nature, sometimes spoken of as bacteriological, were made by me. The remainder of this sample was then turned over to Dr. Robert Zeit for examination. Prof. Zeit's laboratory being in the same building and on the same floor. (States the difference in method employed in the later analyses as compared to the method used in 1886 down to 1890 and 1891 inclusive.)

4121 In these analyses for the periods of 1899, 1900 and 1901 examinations were made for essentially the same determinations as were made in the previous analyses from 1886 to 1890 as heretofore testified to by me, with the addition of the test for nitrites which has just been described. (States number of samples examined from each place in 1899.)

4122 (Motion by Mr. Jeffries to strike out statement in

reference to samples analyzed from water in rivers tributary to the Illinois.)

123 (Witness produces large and small bottle used in taking samples.) I believe these bottles are essentially milar to the ones used by the St. Louis experts for the collection of water.

124 I have the results of these analyses in printed form, as they appeared in my reports to the Illinois State Board f Health published by authority of the Secretary of that Board, overing 1899 and 1900. The proofs for that report were sent o me for comparison with the original manuscript and notes. his comparison was made, and to the best of my belief the figures given in this report are correct.

125 In addition to the ordinary generally recognized chemical tests, I made a certain number of tests which have been escribed as bacterial, but which are really of a nature of chemal tests or reactions intended to show the presence of organic atter in the living or organized forms. These tests included an stimation of the amount approximately of this organized oranic matter described usually as a count of the colonies. That nbraced also a test of the water with reference to the organic rms in it which are able to produce a certain kind of fermention in the liberation of gases. It embraced also a determinaon of the behavior of water with reference to its power of libating or forming acids from certain sugars, recognized by the agulation of milk, and finally, it embraced a test for those ving forms in water which are able to decompose or break own protein matters with the production of a substance known s indol. These tests being in a measure quantitative, as well s qualitative, that is, they give an indication of the kind of rganized organic matter present, and also to some extent, of he amount of this organic matter present. These tests were ade by the methods usually employed by bacteriologists or chemists in the examination of waters.

126 (States method employed in making these tests.)

127 The results of these tests are incorporated in the tables

of analyses made by me at my laboratory from the water taken from the points heretofore testified to.

4128 The tables prepared by me for the 1899 series are in printed form as they appeared in the report of the State Board of Health. These tables are cut from two volumes of this report and pasted on sheets of paper. These tables are true and correct copies of my original sheets. They are numbered from Table No. II up, beginning at Bridgeport. The first I have here is numbered II, in Roman. They were prepared by me in my official capacity as chemist to the State Board of Health. Table No. II appears on pages 12 and 13 of the State Board of Health report, published in 1901.

4130-1 Table No. II showing result of analyses of water at Bridgeport pumping station in 1899.

4132-3 Tables Nos. III and IV giving results of analyses of Des Plaines river water taken in 1899 at Lockport. No. III being canal water and No. IV Des Plaines river water.

4134-5 Table No. V giving results of analyses of canal water taken at Joliet in 1899 and Table No. VI giving result of analyses of Kankakee river water at Wilmington in 1899.

4136-7 Table No. VII giving results of analyses of Illinois river water taken at Morris in 1899 and Table No. VIII giving results of analyses of Illinois river water taken at Ottawa in 1899.

4138-9 Table No. IX giving results of analyses of Fox river water taken at Ottawa in 1899 and Table No. X giving results of analyses of Illinois river water taken at La Salle in 1899.

4140-1 Table No. XI giving results of analyses of the Vermilion river water taken at La Salle in 1899 and Table No. XII giving results of analyses of Illinois river water taken at Henry in 1899.

4142-3 Table No. XIII giving result of analyses of Illinois river water taken above Peoria at the point described as the Narrows, in 1899. This point also being known as Averyville,

and Table No. XIV giving results of analyses of Illinois river water taken below Peoria opposite a point known as Wesley and sometimes described as Lower Peoria.

4144-5 Table No. XV containing results of analyses of Illinois river water collected at Peoria in 1899 and Table No. XVI giving results of analyses of Illinois river water collected at Havana in 1899.

4146-7 Table No. XVII giving results of analyses of Spoon river water collected near Havana in 1899. Table No. XVIII giving results of analyses of Sangamon river water collected near Browning in 1899.

4148-9 Table No. XIX giving results of analyses of Illinois river water collected at Pearl in 1899.

4150-1 Table No. XX giving results of analyses of Illinois river water collected at Grafton in 1899. Table No. XXI giving results of analyses of Mississippi river water collected above Grafton in 1899.

4152-3 Table No. XXII giving result of analyses of water from Kankakee river at South Bend in 1899. Table No. XXIII giving results of analyses of Fox river water at McHenry in 1899. Table No. XXIV giving results of analyses of Des Plaines river water collected at Libertyville in 1899 and in January, 1900.

4154-5 Table No. XXV giving results of analyses of Sangamon river water collected at Mahomet in 1899. Table No. XXVI giving results of analyses of Mackinaw river water collected at Kappa in 1899. Table No. XXVII giving results of analyses of Spoon river water collected at Dahinda in 1899.

4156-7 Table No. XXVIII giving results of analyses of Big Vermilion river water collected at Pontiac in 1899. Table No. XXIX giving results of analyses of West DuPage river water collected at Winfield, sometimes described as Wheaton in 1899.

4158 I have a table of averages prepared from the preceding tables of analyses which I have read into evidence. That

table was prepared by me and is a true and correct table of averages based upon the preceding tables of analyses. (Objection by Mr. Jeffries to the reading of table of averages and there was also objection to the reading of all the foregoing tables.)

4159 Table No. XXX giving result of analyses made in 1899 of the waters indicated in the preceding tables. From a consideration of the tables presented and from the tables of averages drawn from these individual tables, these general conclusions may be reached:

4160 First: That the first and most general examination of this table shows a very great diminution in the organic pollution of the Illinois river and its tributaries, and the source between Bridgeport and Upper Peoria or Averyville, a diminution of the organic matter which cannot be accounted for by the dilution from the tributary waters as shown approximately by the decrease in the chlorine contents. This decrease in organic matter is explained by a consideration of several factors. We find in considering data given for oxygen absorption or oxygen consumption in the filtered water as well as in the unfiltered water, that between Bridgeport and Peoria there is a very marked decrease, a point being reached finally where the organic matter as disclosed by the oxygen consumption test does not appreciably differ from that found in the tributaries of the Illinois as shown by the same test. I find also a very marked decrease in the amount of the product indicated by the albuminoid ammonia, a decrease from over 3 parts per million to .57 parts per million. This last amount being not a great deal different from that found in several of the tributaries of the Illinois. I find also in considering this table a very marked change in the decrease in the amount of the so-called free ammonia, the decrease here being very nearly from 20 parts per million to less than one part per million, this decrease being in a measure, an index of the extent of bacterial oxidation or purification

which has taken place in this part of the stream. We observe also in the figures showing the amount of nitrogen present in the form of nitrates, that a very great oxidation has taken place in the Illinois river, the nitrates resulting from the bacterial oxidation of the nitrogen which has previously existed in some other form, and which has gone through the stage of free ammonia. We observe also the appearance of nitrites in considerable amounts in the lower stretch of this part of the river. The nitrites indicating also the advance of oxidation. A very noticeable feature of these tables is that after Upper Peoria or Averyville, or the Peoria Narrows is passed, the condition of the river as disclosed by the analyses shows a very marked organic pollution again. We find that below Peoria the amount of organic pollution as measured by the albuminoid ammonia is very nearly as great as that observed in the canal at Bridgeport. We find also in passing Peoria that the free ammonia has increased from less than one part per million to over four parts per million. We find also that the figures measuring the oxygen consumption in passing Poria have increased in the case of the unfiltered water from over six parts per million to over 17 parts per million, and the figure indicating the oxygen consumption in the filtered water has increased approximately from five and one-half parts per million to nearly thirteen parts per million. This remarkable increase in the numbers given shows that at this point a very great amount of organic matter has been added to the Illinois river. From the investigations which I have myself made at different times, an explanation of this increase is given. It is a matter of personal investigation and also of common knowledge that in the city of Peoria there are great industries which discharge waste of a highly organic nature into the Illinois river and the samples of water collected at Wesley were taken from a point below the discharge of these industries. These industrial wastes are mainly from distilleries and from cattle sheds in which cattle feeding on the slops of these distilleries are kept, and from glucose factories. Coming down the river from Peoria we observe again, as we did in coming

down from Bridgeport to Peoria, a very marked gradual decrease in organic contamination. This decrease is observed in a gradual fall in the figures indicating the oxygen consumption in the filtered and unfiltered water and in the free ammonia and in the albuminoid ammonia so that a change takes place in the Illinois river below Peoria, and is due to the same general causes, as indicated by the amount and character of the products given here, as takes place in the river above Peoria, so that finally, at the mouth of the river at Grafton, we have reached a condition in which the factors for organic pollution are not greatly different, or essentially different from those observed in the tributaries of the Illinois river. Taken as a whole, then, these tables disclose two main sources of contamination of the Illinois river, first, the sewage from the city of Chicago which decreases very greatly before Peoria is reached, and secondly, the industrial wastes from the city of Peoria, which decrease greatly before the mouth of the river at Grafton is reached. A consideration of these figures shows beyond any question whatever that the main factor in the contamination of the Illinois river at its mouth is not the waste or sewage contributed from Chicago, but the industrial waste contributed from the various industries of the city of Peoria.

4164 (Objection by Mr. Jeffries and motion to strike out.)

In comparing the results of the analyses made for the canal and the Des Plaines river at Joliet, and the obtained analyses of the Illinois river water at Wesley, we see that the number for the albuminoid ammonia is greater at Wesley than it is at Joliet, indicating a larger amount of protein products, decomposable in the albuminoid ammonia distillations at Wesley, than is found in the Des Plaines river and canal at Joliet. We have also the albuminoid ammonia at Joliet, being measured by 2.88 per million, while that at Wesley is measured by 3.2 per million. This average being drawn from individual experiments which are comparable in time and number. It is seen from comparing Joliet with Wesley, that we have at Wesley, as indicated by the oxygen consumption, an amount of organic

matter almost as great as at Joliet, in the filtered water. In the filtered water of Joliet, the oxygen consumption being 15.1 parts per million, while at Wesley it is 12.84 parts per million. In the water not filtered the oxygen consumption number is 25.9 parts per million at Joliet, and 17.44 parts per million at Peoria. As the waste of Peoria is known to be largely of a nitrogenous character, this difference in the numbers is simply and easily accounted for, the oxygen consumption number being relatively greater at Joliet, and the albuminoid ammonia numbers being relatively greater at Peoria; the albuminoid ammonia numbers measure most fairly the protein condition of contamination. (Motion to strike out by Mr. Jeffries.)

The comparison of the water at Joliet with that at the Peoria Narrows is very instructive, the condition of the water at Joliet in every way being much worse than that at the Narrows. In my analyses the numbers given for oxygen consumption and for free ammonia and albuminoid ammonia, indicate at Joliet a very highly polluted condition, such as we find in the waters of marked sewage contamination, while at the Peoria Narrows the numbers given for oxygen consumption and free ammonia and albuminoid ammonia are not greatly different or essentially different from those which are found in the waters of the ordinary streams of the State of Illinois, not unreasonably contaminated, or not contaminated with anything more than is taken up by the passage of these waters through a soil rich in ordinary orga ic matters.

4165 The water of the Fox river at Ottawa contains as indicated by the oxygen consumption test, practically as much organic matter as that contained in the Illinois river water at the Narrows, the average result showing a greater oxygen consumption for the filtered water of the Illinois at the Narrows. While the oxygen consumption results for the unfiltered water at Ottawa are slightly greater than for the unfiltered water at the Narrows, the free ammonia figure of the Fox river water at Ottawa is very much less than the free ammonia figure for the Illinois river water at Peoria, the free am-

monia at this place, the Narrows, not yet having undergone complete oxidation. In the case of the albuminoid ammonia figures, the amount in the Fox river at Ottawa is almost as great as that of the Illinois river or canal, both figures being in the proportion that we find in the ordinary streams of the State of Illinois, flowing through soil containing a large amount of organic matter. By a consideration of the figures given for the analyses of the Illinois at La Salle and at Pekin, these relations are observed: The organic matter as indicated by the albuminoid ammonia at Pekin is very much greater than the organic matter indicated by the albuminoid ammonia at La Salle; the amount of free ammonia at La Salle on the contrary is greater than the free ammonia found at Pekin.

4166 That indicates that the oxidation of the free ammonia at La Salle has not gone as far as the oxidation of the ammonia at Pekin. In the case of the contamination as measured by the oxygen absorption, the condition at Pekin is very similar to that at La Salle, the numbers being nearly the same. In comparing the waters of the Illinois river at Peoria and the Peoria Narrows, and Grafton, we find as measured by the oxygen consumption figures and by the free and albuminoid ammonia figures somewhat more organic matter indicated at Peoria than at Grafton, but not a great deal more. As indicated by the oxygen consumption test, the Mississippi river water at Grafton contains more organic matter than the Illinois river water at Peoria Narrows. As indicated by the figures for free ammonia, oxidation has gone very much further in the Mississippi river at Grafton than at the Narrows at Peoria. As indicated by the albuminoid ammonia test, the organic matter in the Mississippi river at Grafton is about eighty per cent of that in the Illinois river at the Peoria Narrows. As measured by the oxygen consumption test, the Mississippi river water at Grafton contains more organic matter than the Illinois river water at Grafton. As measured by the albuminoid ammonia, the Illinois river at Grafton resembles very closely the Mississippi river water at Grafton.

4167 The other determination shows that in the Illinois river water at Grafton we have evidence of a large amount of nitrogenous matter which has undergone oxidation. Nitrites for example, at Grafton, or the Illinois river at Grafton, being nearly twenty times as great as the nitrites in the Mississippi river water at Grafton. We have also in comparing the Mississippi with the Illinois river at Grafton this fact, that of the unoxidized ammonia we have in the Illinois river about three times as much as in the Mississippi river water. From a consideration of all these tables and averages, the conclusion is a necessary one, that the organic matter discharged at Bridgeport into the canal and subsequently into the Illinois river, has undergone practically complete oxidation before the mouth of the Illinois river is reached at Grafton, because at this point we find no more organic matter than can be accounted for readily by that discharged from the tributaries and from the contamination at Peoria. I have made analyses of the Des Plaines river above Lockport and am acquainted with that river above that point.

4168 I am familiar with the towns on the river and the character of the drainage entering the river. The Des Plaines river is a sluggish stream which drains a number of suburban towns around Chicago. One of these is the town of Riverside, which is not far above the controlling works at Summit, north of Summit. The Town of La Grange is also in part drained into the Des Plaines, the sewage of La Grange flowing into a small stream, a small creek which in turn enters the Des Plaines near Riverside. Above Riverside there are several towns located on the Des Plaines, the drainage of which is taken up by that stream. Maywood is one and Norwood Park is another. The Des Plaines furnishes the only outlet for drainage for these various towns, and when it becomes mixed with the canal water, it is not a potable stream and has not been in a great many years, not in twenty years.

I have made analyses at the point where the Bear Trap dam is located, which is at Lockport. I should not consider from these analyses that the water of the Des Plaines river at that point is safe and potable water. From my analyses and from my present knowledge of the Des Plaines river above Lockport and of the towns that empty their sewage into the river, I should not consider that a safe and potable river.

4169 The Des Plaines river is extremely variable. At times of high water it carries a flood but in dry season it is almost dry. It contains little more than the sewage from the towns draining into it. I have testified as to the chemical results of the 1899 investigation. The bacterio-chemical results agree in a general way with the chemical results, in showing the condition of extreme organic contamination at Bridgeport, Lockport and Joliet, which show gradual improvement as we go down the river until Peoria is reached—Upper Peoria or the Narrows, or Averyville, as it is called, where the individual results obtained by the various methods which I referred to this morning do not differ essentially from similar results obtained from the tributaries of the Illinois. But leaving Peoria Narrows and going down to Wesley, we find as indicated by these bacterio-chemical results, great marked increases of contamination again. The number of forms of organic matter in the organized condition, or living condition at Lower Peoria or Wesley

4170 as disclosed by what is called the colony count, is certainly as great as that found at Bridgeport, while the factors indicating the fermentation of carbo-hydrates by the bacteria present and indicating the presence of those bacteria which convert carbo-hydrates into acids and coagulate milk, are likewise as great at Wesley as at Bridgeport, so these bacterial results then in general agree with the chemical results in showing an enormous increase in pollution, as Peoria is passed, and these chemical bacterial results show as we leave Peoria and go down the river, a gradual diminution in the organized forms until the mouth of the river is reached at Grafton, where the number of bacteria present, and the behavior of the bacteria

with the reagents mentioned, show a condition similar to that found in many of the tributaries of the Illinois. I have the table of analyses compiled by me for the samples of water taken in 1900. These tables correctly state the results of my analyses as made in the manner heretofore stated in my testimony.

4171 I have in 1900, two sets of tables, one embracing examinations made shortly after the drainage canal was opened in the spring of 1900 and the other taking up a later period in the same year.

4172-3 Table No. XXXII gives result of one examination of water from Bridgeport Pumping Station and I. & M. canal, made March 6, 1900. Table No. XXXIII giving results of analyses of water from the main drainage canal, water being taken at Western Avenue bridge between March 13 and April 25, 1900.

4174-5 Table No. XXXIV giving results of analyses of Illinois river water taken at Morris, in the spring of 1900. Table No. XXXV giving results of analyses of Illinois river water taken below Peoria, opposite Wesley, in March and April, 1900. Table No. XXXVI giving results of analyses of Illinois river water collected at Havana in March and April, 1900.

4176-7 Table No. XXXVII giving results of analyses of Spoon river water taken near Havana in March and April, 1900.

4178-9 Table No. XXXVIII giving results of analyses of Illinois river water taken at Pearl in March and April, 1900. Table No. XXXIX giving results of analyses of Illinois river water taken at Grafton in February, March and April, 1900.

4180 Table No. XL giving averages of the results of analyses made in the spring of 1900 of samples of water taken at the places indicated in the previous tables.

4181 From these various tables I note that the amount of organic matter at Bridgeport in the old canal and the drainage canal at Western Avenue is less than disclosed by the previous analyses given in 1899. An exact comparison is how-

ever difficult because of the fact that in this period, in the spring of 1900, the water flowed through both canals, through the Illinois and Michigan canal and through the drainage canal, but not at a constant rate, so that an exact comparison of these figures is difficult. However, as we proceed down the river to Morris, where there is a complete mixing of the waters, we find for the numbers representing the free and albuminoid ammonia a lower amount than disclosed in the analyses made in 1899. When Lower Peoria or Wesley is reached, there is here a very great increase in the figures for all constituents. In the factor representing the oxygen absorption, the free ammonia and the albuminoid ammonia the increase is very marked. Following below Peoria, we observe a decrease in these factors, representing or pointing to the amount of organic matter present. We find at Pearl that the factors for oxygen consumption and for albuminoid ammonia are as low as in the 1899 examinations in general, and as low as disclosed in the waters of many of the tributaries of the Illinois. We find at Grafton, however, below Pearl, for some reason which cannot be given, a slightly larger amount of organic matter in the mean, than at Pearl, but the point of greatest importance in this table is the very marked increase of the organic matter at Peoria and at Wesley, the point below Peoria, as compared with the amount found at points above during this same examination.

4182 A comparison between the waters at these points is a fair one because they were collected through the same months and shows this: that at Wesley, below Peoria, the organic matter as measured by the oxygen absorption and by the albuminoid ammonia and as indicated also by the results of the bacterio-chemical examinations, is greater than that found at Morris through the same period. Any increased dilution below Morris would tend to decrease rather than increase the contamination at Peoria, making it appear even more strongly. The organic matter is larger than at Morris. At Grafton, the various factors given in the table show a lower condition of contamination than at Morris, in practically all cases. At

Morris in 1900, after the opening of the drainage canal the amount of albuminoid ammonia is very much less than the amount found in 1899, before the opening of the drainage canal. The factor for oxygen coasumption in 1899, is, in the filtered water somewhat greater than for the filtered water in 1900, but for the unfiltered water, slightly less.

4183 That indicates simply as stated, that the amount of organic matter is less one year than the other, to make that direct comparison. At Wesley, in 1899, in the mean, as indicated by the albuminoid ammonia, there was more organic matter present than in 1900, as indicated by the oxygen consumption; also somewhat more in 1899 than in 1900. The free ammonia at Wesley in 1899 is greater than that at Wesley in 1900. It contains less pollution in 1900 than it showed in 1899. At Havana, in 1899 the amount of organic matter as measured in parts per million by the free and albuminoid ammonia was greater than in 1900, and the oxygen consumed shows a somewhat similar condition. The oxygen consumed is a little greater in the spring of 1900 than in 1899. As measured by the albuminoid ammonia, in a given volume of the water, the analyses showed that there is a greater pollution in 1899 than in 1900. While as measured by the oxygen consumption the result for 1900 appears to be slightly greater than the result for 1899.

4184 At Pearl, as measured by the oxygen consumption, the organic matter in parts per million is greater in 1900 than it is in 1899, but as measured by the albuminoid ammonia present, the contamination in 1899 is greater than that in 1900. Comparing the river through the summer of 1899 at Grafton, with that at Grafton through the spring of 1900, we find that the condition at Grafton shows more organic matter from a given volume in 1900 than it does in 1899. This comparison, however, is made between the river at the time of high floods in the second year and through the summer conditions in the first year. From the fact that these analyses which I last gave, made in 1900, were carried out in the spring of that year,

4185 when the waters in general were high, any comparison between the river at this time—the lower stretches of the river at this time, with the lower stretches of the river in 1899, is impossible—any fair comparison is impossible. The Illinois river in the spring of 1900 in its lower stretches shows the condition of the ordinary western rivers at the same time, irrespective of the source of their contamination. We have here the large amounts of free and albuminoid ammonia, and high figures for oxygen consumption, which are found in the ordinary tributaries of the river. A comparison in this table is important mainly as it shows the increased contamination at Peoria or Wesley. (Witness states number of samples taken at the various points indicated during the spring of 1900.)

4186-7 Table XLII giving results of analyses of water of the Illinois and Michigan canal at Bridgeport, collected in July, August and September, 1900.

4188-9 Table No. XLIII giving results of analyses of water from main drainage canal at Western Avenue bridge in June, July, August and September, 1900. Table No. XLIV giving results of analyses of water from the drainage canal at Lockport in June, July, August and September, 1900.

4190-1 Table XLV giving result of analyses of water at Joliet, being a mixture of water from both canals and the Des Plaines river, collected in June, July, August, September and October, 1900. Table No. XLVI giving results of analyses of water of the Illinois river at Morris in June, July, August, September and October, 1900.

4192-3 Table XLVII giving result of analyses of water of the Illinois river at Ottawa in June, July, August, September and October, 1900. Table No. XLVIII giving results of analyses of water of Fox river in June, July and August, 1900.

4194-5 Table No. XLIX giving results of analyses of water of Illinois river at La Salle in June, July, August and September and October, 1900. Table No. L giving results of

analyses of waters of Vermilion river at La Salle in August and September, 1900.

4196-7 Table LI giving results of analyses of water of Illinois river at Henry in June, July, August, September and October, 1900.

4198-9 Table No. LII giving results of analyses of water of Illinois river at Upper Peoria, or the Narrows, or Averyville, in June, July, August and October, 1900. Table No. LIII giving results of analyses of waters of Illinois river collected at Wesley or Lower Peoria in May, June, July, August, September and October.

4200-1 Table No. LIV giving results of analyses of waters of the Illinois river at Pekin, in May, June, July, August and September, 1900. Table No. LV giving results of analyses of waters of the Illinois river at Havana collected in June, July, August, September and October, 1900. Table No. LVI giving results of analyses of waters of the Spoon river collected at Havana in July and August, 1900.

4202-3 Table No. LVII giving results of analyses of waters of the Illinois river at Pearl, collected in June, July, August and October, 1900. Table No. LVIII giving results of analyses of Illinois river at Grafton in June, July, August and September, 1900.

4204-5 Table No. LIX giving results of analyses of Mississippi river at Grafton in July, August and September, 1900. Table No. LX giving results of analyses of waters of the Sangamon river opposite Browning, collected in August and September, 1900. Table No. LXI giving results of analyses of waters of the Kankakee river near Wilmington, collected in August and September, 1900.

4206 (Motion by Mr. Jeffries to strike out tables referring to the tributaries of the Illinois river.)

4207 Table No. LXII giving averages of results of analyses of

water at the points referred to in preceding tables.

(Witness states numbers of samples and places at which same were taken in summer and autumn of 1900.)

4208 These tables considered in comparison with each other,
and a consideration of the averages of the tables for the
4209 work of the summer of 1900, show in general, to begin with, a lower initial contamination of the water at Bridgeport than was the case in the examinations of the waters made in the previous year, 1899. The tables show further, as we proceed down the river and canal from Bridgeport to Lockport and Joliet, and down the Illinois river proper a gradual and continuous diminution in the factors indicating the organic contamination, and to an extent which is very much greater than can be accounted for in any way by the amount of dilution coming in from the tributaries. An examination of these tables shows first, in general, a marked reduction of organic matter as compared with the amounts present at the source of contamination—Bridgeport, in the main drainage canal. At the Narrows above Peoria, the factors indicating the extent of organic pollution as drawn from the results of the oxygen consumption test, and the free and albuminoid ammonia tests are not greater than those found from an examination of the ordinary tributaries—from the ordinary tributary waters of the Illinois in this State. We find also on further consideration of the table that after Peoria Narrows is passed and the next point is reached, a remarkable increase in the organic pollution again, as measured by the important factors already referred to, the oxygen consumption and free and albuminoid ammonia, this increase being in the free and albuminoid ammonia several hundred per cent. The figures for oxygen consumption increase are likewise very large. The increase, from the known nature of the contaminating material entering the river at Wesley is largely nitrogenous, and hence the much greater increase apparent in the figures for free and albuminoid ammonia than that apparent in the figures for oxygen consumption. Below Peoria as we proceed down the river we observe a decrease

again in these figures—a decrease in the oxygen consumption by the water, a decrease or disappearance of the free ammonia, and a very marked decrease in the albuminoid ammonia at Pekin. At the points below Pekin there is but little further decrease in the albuminoid ammonia for the reason that we have reached here a condition in the amount of albuminoid ammonia which is comparable with that found in the ordinary rivers of the State, beyond which the reduction does not commonly proceed to a great degree, for the reason that we have reached here the comparatively stable types of organic substances which are not much subject to reduction by the bacterial oxidizing agents. In the case of the free ammonia, however, as this substance does undergo change, we find a progressive improvement or disappearance by oxidation to the mouth of the river, the figure for free ammonia at Grafton being .07 parts per million. In considering the indications given by the figures for the oxygen consumption we have a similar condition. Below Pekin there is a general gradual decrease until Grafton is reached, where the figures for the oxygen consumption again have sunk to a point corresponding to those given by the waters of the tributaries entering the Illinois, and by waters of this type in general, which flow through soil containing a large amount of organic matter. These figures for oxygen consumption have reached a point which is not passed in the waters of this region when exposed to the contamination of ordinary organic substances of vegetable origin. In drawing full comparisons in this table, it is necessary to make, to begin with, a calculation of the combined flow through the main drainage canal and the Illinois and Michigan canal. Inasmuch as the water reaches the Des Plaines river at Joliet through two canals, carrying unequal portions and drawing different kinds of water, it is necessary to make a calculation of this kind in order to have a starting point for the comparison. The calculation which I refer to is to determine what the constituents present would amount to on the supposition that all the water was carried through one channel instead of two, because in considering the points further down

the stream, we are dealing with only one channel. In order to make a computation of this flow I have taken from the published tables of the chief engineer of the Sanitary District the flows through the two canals at the periods in question, and have combined them in such a way as to obtain the total flow. Knowing the total flow in each canal it is a matter of arithmetical calculation to find what the content would be on the supposition that all of the water passed through one channel. During the period in question, as deduced from the tables of the chief engineer of the Sanitary District, about sixteen per cent of the flow was through the old, or Illinois and Michigan canal, and about eighty-four per cent of the flow through the main drainage canal, and these figures were used in a calculation which I will next present, which, however, has not been carried out for all constituents but only for the most important ones. Assuming that all of the water passed through one channel, the volume being equivalent to the volume flowing through the two channels, the constituents in that one channel would be this: Chlorine 23.5 parts per million. Free ammonia—

JUDGE SPRINGER: At what place is this?

A. This is the assumed entrance of the one channel at Bridgeport, supposing the water all went through one, instead of through two.

| | | |
|---|---|---|
| Chlorine | 23.5 | parts per million |
| Free ammonia | 3.9 | " |
| Albuminoid ammonia | 1.13 | " |
| Oxygen consumption in unfiltered water | 7.46 | " |

These numbers may be taken as representing then the composition of the total flow through the combined channels. It will be seen by comparing these numbers which I have just given, with those given for the water at Joliet, that there is a discrepancy in some of the figures. That discrepancy depends on this fact, that, at Joliet in the basin there is not, or was not at all times, a perfect mixture of the Des Plaines and main drainage canal water, and the old canal water, so that the re-

sults are somewhat dependent on the point there at which the samples were taken, and at the times there at which the samples were taken. Because of that discrepancy the Joliet collection is not considered in the comparison that I wish to make. With this calculated composition of the canal on the assumption that the water all flows through the one channel, I have made some graphic charts which illustrate the variations in the amount of substances present, expressed in parts per million in the whole flow between Bridgeport and Grafton at the mouth of the river, these charts illustrating somewhat more clearly and plainly the variation than do the figures as read from the tables. The first chart shows a decrease in the chlorine, which is a measure approximately, of dilution by tributary waters.

4212 (Objection by Mr. Jeffries.)

4214 Chart representing the decrease in chlorine present expressed in parts per million, between Bridgeport and Grafton as determined by the examinations of the Illinois river water, made during the summer of 1900.

4215 (Witness explains significance of figures on the chart.) In this chart we have a decrease of the chlorine from Bridgeport to La Salle; an increase at Henry corresponding to the chlorine coming into the river at or below La Salle from the industries there present, largely. A further decrease to Upper Peoria; a slight increase at Wesley; a decrease at Pekin; about the same amount at Havana, and a gradual decrease to the mouth of the river.

4217 Chart representing change in the amount of free ammonia present in the water between Bridgeport and Grafton for the period of the summer of 1900. That chart being drawn from the average of results of chemical analyses made through that period. The chart indicates a very great decrease in ammonia from the starting point, until Upper Peoria is reached, and then a remarkable increase—followed by a decrease to Pekin.

4218 I have also a chart for albuminoid ammonia prepared from the results of analyses made in the summer of 1900

from Bridgeport to Grafton. We have, beginning at Bridgeport, the amount of albuminoid ammonia, calculated for the assumed flow of water through one channel in place of two, 1.13 parts of albuminoid ammonia per million. This amount decreases rapidly to Morris and then to Ottawa, where the amount found is below .4 of a part per million. A further decrease takes place at La Salle; then a slight increase to Henry, where the amount present is almost exactly .41 of a part per million. We have then a further slight decrease until Upper Peoria or Averyville is reached, where the amount reached is .34 of a part per million. From this point a very marked increase takes place at Wesley, at which point the amount of albuminoid ammonia present is .34 parts per million. This amount decreases again rapidly. At Pekin the amount found is below .5 of a part per million; it sinks to Havana where the amount of .41 of a part per million is reached.

4219 A slight increase is observed from here to Pearl where the amount present is found to be .43 of a part per million, and a further decrease to Grafton follows, where the amount is given as .36 of a part per million. The characteristic point in this table is the sudden and great increase of the albuminoid ammonia at Pekin, due to the introduction of fresh organic matter, essentially of protein character, and the rapid decrease as observed at Pekin is due to the remarkable condition of decomposition taking place in the stretch between Peoria and Pekin which has been observable at periods before and after the opening of the main drainage canal.

4220 Chart referred to.

4221 I have also a chart called oxygen consumption curve, which was made from the analyses of the summer of 1900.

4222 This chart illustrates the variation in the oxygen consumption as expressed in the figures of Table LXII heretofore read. This oxygen consumption being given for the points between Bridgeport and Grafton. The abscissa lines have the same significance as already explained, and the ordinate lines represent parts per million of oxygen consumed.

These represent the unfiltered water. We have at Bridgeport an amount of oxygen consumption found to be 7.46 parts per million, which amount decreases gradually to La Salle, and increases slightly to Henry, from which point a decrease follows to Upper Peoria or Averyville, where the amount present is found to be 5.5 parts per million. We have then a very marked increase to Wesley, below Peoria, where the amount present is 9.91 parts per million. From this point a decrease follows again to Pekin, and to Havana, and from Havana there is a slight increase to Pearl, and finally a decrease in the amount to Grafton where the results show 5.85 per million.

(Chart referred to.)

4223 (Motion by Mr. Jeffries to strike out all the charts offered.)

JOSEPH WEIS, examined in chief by Mr. Todd:

4224 I know John E. Thome of the Bridgeport Pumping works. I got the samples that were collected by him at the Bridgeport Pumping works and took them to the city hall and to the University of Illinois and to the University of Chicago.

4225 PROF. JOHN H. LONG, resumed the stand for further direct examination by Mr. Todd:

4226 A consideration of all the tables presented and of the charts drawn from them leads to this important and necessary conclusion: That in the flow of the sewage water from the pumps at Bridgeport through the drainage canal and subsequently into and through the river there is a very remarkable reduction or destruction of organic matter to Peoria; a great increase again between Peoria and Pekin, beyond which the reduction follows which continues to the mouth of the river, and at the mouth of the Illinois river as far as the organic content is concerned, the Illinois river is not more contaminated than are the ordinary tributaries and rivers of this region flowing through a soil which contains large organic matter, and finally, and the most important conclusion to be drawn from these tables and charts is, that the main factor in contamina-

tion of the Illinois river is the addition of sewage, stockyards and distillery waste of the city of Peoria. (Objected to by Mr. Jeffries and motion to strike out.)

4227 I made some chemical examinations in 1901 and the spring of 1902. The points selected in 1901 were: in the Illinois river above Grafton; in the Mississippi river above Grafton, and in the Missouri river above the mouth of that river, or the point where it flows into the Mississippi. This investigation was made the last part of 1901 between the last of September and the middle of December. The next investigation was made in the spring of 1902 in part of February and March, at the same points. Samples for these tests were taken in the manner that I have heretofore testified.

4228 I have tables that were made as the other tables were, from the results of these examinations. They are in the form in which they were printed by the authority of the Illinois State Board of Health, in one of the bulletins or reports of that Board, printed in 1902.

4230 Table No. I giving results of analyses of water of the Illinois river taken above Grafton between September 23, 1901 and December 12, 1901.

4232-3 Table No. II giving results of analyses of Mississippi river water above Grafton between September 23, 1901, and December 12, 1901.

4234-5 Table No. III giving results of analyses of water of Missouri river taken some 600 feet above the mouth of that river between September 17, and December 12, 1901.

4236-7 Table No. IV giving result of analyses of water of the Illinois river above Grafton between February 24, 1902, and March 18, 1902. Table No. V giving results of analyses of water of the Mississippi river above Grafton between February 24, 1902 and March 17, 1902. Table No. VI giving results of analyses of waters of the Missouri river about 600 feet above the mouth of the Missouri in March, 1902.

4238 I have a table of averages prepared by me from these tables of analytical data.

4239 Table read in evidence.

From a consideration of these several tables, I draw the following general conclusions: That the organic condition of the Illinois river above Grafton is very much better than the organic condition of the Missouri river above its mouth. This is shown by several factors. By the factor measuring the oxygen absorption, which for the Illinois river is for the unfiltered water, 4.31 parts per million, and for the filtered water, 3.21 parts per million. For the Missouri river, for the unfiltered water, 10.28 parts per million, and for the filtered 3.17 parts per million. By the factor for the albuminoid ammonia, as measuring the substances of comparatively complex composition to be yet decomposed, 0.413 parts per million in the Illinois, as against .6 parts per million in the Missouri. By the factor measuring the organic ammonia, as determined by the Kjeldahl process, which is .81 parts per million for the Illinois, as compared with 1.61 parts per million for the Missouri. As measured by the oxygen absorption, the Illinois river contains less organic matter above its mouth than does the Mississippi river.

4240 As measured by the albuminoid ammonia, the Illinois river contains very nearly the amount of organic matter that is contained in the Mississippi river. As measured by the organic ammonia determined by the Kjeldahl process, the amount in the Illinois river is not greatly different from that in the Mississippi river. Considering the chemical reactions due to the living organic matter in the Illinois and the Missouri rivers, it is evident that the condition of the Illinois is very greatly superior to that of the Missouri, throughout the whole period. This is especially shown by the chemical determinations made to indicate the presence of those living organisms which decompose protein matters, with the production of indol. The reaction for indol is found at the mouth of the Illinois river above Grafton very rarely, while in the Missouri river 600 feet above its mouth, this reaction is extremely common, showing a very much greater number of the living organ-

isms capable of bringing about this peculiar chemical decomposition in the Missouri river than are found in the Illinois river. From the information obtained from the tests for the presence of those organisms, which have the power of breaking down carbo-hydrates, with the liberation of acid, which subsequently coagulates milk, it is likewise evident that the contamination in the Missouri river is very much greater than the contamination in the Illinois river through the same period. The number of acid forming organisms as disclosed by the results of the tests being greater in the Missouri than in the Illinois. It also appears by a comparison of the tables in which a determination of the number of living organisms was made by the so-called colony count process, that the Missouri river shows a greater contamination than does the Illinois, through this same period. In its organic condition as indicated by these chemical tests which I have described as sometimes called bacterial, although they involve true chemical reactions, the Illinois river is as pure as the Mississippi at the point of junction of the Illinois with the Mississippi, and the Illinois river is very much purer than the Missouri at the point where the Missouri flows into the Mississippi.

4241 When we turn to these results just given as applied to a comparison of the results for the fall of 1901, and when we turn to the results obtained in the spring of 1902, the same general conclusions follow. The indol reaction is more common in the Missouri river than it is in the Illinois. The purely chemical tests indicate the presence of a larger amount of organic matter in the Missouri river than is indicated in the Illinois. It is, beyond question, true, that at the period of this investigation the Illinois river at its mouth, was a much less contaminated stream than the Missouri river at its mouth. As disclosed by the experiments described, the Missouri river is far more contaminated organically than the Mississippi at the points at which the samples analyzed were taken. I also examined the waters of the Kaw and the Missouri rivers. I am familiar with the Kaw from its mouth for a distance of 100

miles or more west. I lived for a number of years on the Kaw and have been on it at numerous points.

4242 This investigation was made in the Kaw at a point above its entrance into the Missouri; in the Missouri above Kansas City, and above also the confluence of the Kaw; in the Missouri below the entrance of the Kaw and finally in the Missouri below Kansas City. I suggested and directed the locations for taking the samples, to Mr. Quinlan and Mr. Burke, the employes of the Sanitary District of Chicago. I instructed these men to go to Kansas City and collect samples at each point I have mentioned, in May, 1903. They were to be taken on three days, three samples on each day, a sample from the middle of each stream and from near the right and left banks, making a cross-section of three points.

4243 These samples were received by me and I used these waters for the determination of the amount of chlorine present. I made no other special determinations. I secured from the engineer of the United States Geographical Survey at Washington the volumes of the Kaw and Missouri rivers. For the Kaw, at the town of Lecompton, Kansas and for the

4244 Missouri, at a point a short distance above the city where the gauge is read. Lecompton is in Kansas on the Kaw, about forty miles above its mouth. The volumes of these rivers is given in cubic feet per second as follows:

For the Kaw:

May 24, 1903, 51,000
May 25, 1903, 49,600
May 26, 1903, 39,100
May 27, 1903, 63,500
May 28, 1903, 72,200

4245

For the Missouri:

May 22, 1903, 125,000
May 23, 1903, 145,000
May 24, 1903, 184,000
May 25, 1903, 198,000

May 26, 1903, 226,000

May 27, 1903, 242,000

May 28, 1903, 310,000

I have a table of analyses for chlorine. This table shows the results of the examinations of the Missouri and Kaw rivers. (Table read in evidence.) The general averages shown by this table are as follows, being the parts of chlorine per million:

Kaw river, one and one-half miles above Kansas City, general average, 9.71;

Missouri river above Kansas City, general average, 10.67;

Missouri river below mouth of the Kaw, general average, 10.97;

Missouri river below Kansas City, general average, 12.31.

4246 (Motion to strike out by Mr. Jeffries.)

4247 The averages drawn from these tables show a considerably larger figure for chlorine below Kansas City, than in the Kaw or in the Missouri above Kansas City. The excess of chlorine below Kansas City being more than can be accounted for by any addition from the Kaw, and showing the fact that a certain proportion must come from the stock yards industries, and the sewers of Kansas City. The volume

4248 of the Missouri river is very considerably greater than the volume of the Kaw throughout this period, and the amount of chlorine in the Kaw, taking its volume into consideration, cannot act to increase the amount of chlorine in the Missouri above the figure given for the Missouri above Kansas City. My analyses of the waters of the Missouri river in 1902 disclose relatively high chlorines in that river. The chlorine in the Missouri river is always much higher than the chlorine in the Mississippi river. The chlorine at the mouth of the Missouri river can be attributed only in part to the chlorine of the Kaw river, the tables showing that the additions from Kansas City is an important factor. The analyses show considerably less chlorine above Kansas City than below Kansas City, at the time the examinations were made.

4249 The chlorine below Kansas City is considerably greater

than the chlorine in the Kaw. It is my opinion that I gave sufficient data to draw a fair conclusion in this case. That was my opinion before I ordered the samples taken.

Q. How did the chlorine below Kansas City compare with the chlorine in the Missouri river at its mouth, in the examinations as made by you in 1902?

MR. JEFFRIES: We object to the question for the reason that the conditions under which the samples were taken are not shown to have been the same or shown to have been taken under conditions which would be comparable with each other and we object to the question for the further reason that the evidence showing pollution of the Missouri river is not justification for the Sanitary District of Chicago polluting the waters of the Illinois river by the discharge of the sewage from Chicago into it.

A. It is not possible or profitable to make comparison here because the samples were not collected at the same time or under identical conditions.

4250 From all the examinations I made of the Illinois river and its tributaries, it is my opinion that no part of the original organic matter leaving Chicago through the sanitary canal and finding its way into the Illinois river, can reach the mouth of the Illinois river, and much less the intake tower of the St. Louis waterworks. It is my belief that the sanitary condition of the water supply of St. Louis is not and cannot be injured by any pollution passing through the drainage canal from Chicago to the Illinois river and down. As the sewage is disposed of in two general ways, practically by dilution and by oxidation, or chemical destruction through bacterial means—inasmuch as the volume of water is greatly increased, the diminution of the sewage for a given volume, per cubic centimeter, for example, or per liter, is necessarily less, and inasmuch as at the same time with this new dilution there is no decrease enforced in the bacterial activity throughout the channel, so there can be no decrease in the purification from those causes. We have remaining, the diminution of organic matter by

dilution, making the final effect better rather than a worse condition of the river.

The volume of water going down the Illinois river is now greater than it was before the opening of the drainage canal.

4251 I am acquainted with the Illinois river in flood time.

The effect of very high water in the Illinois river is a complicated one. The floods carry into the river an immense amount of organic matter from all the tributaries and numerous living organisms or bacteria which are practically always associated with this organic matter. The floods in general, from the gathering up of this large amount of organic matter, have the effect of increasing the organic contamination irrespective of any original contamination which may have been present. A further effect of these floods, inasmuch as the banks of the Illinois river are very low, is to spread an enormous volume of water over an area of many hundreds of thousands of acres, providing for the sedimentation and oxidation to a marked degree, of the matters carried by the waters at these periods. The conditions in the Illinois river because of the peculiar character of the banks, are unique in this respect. The overflow disposes in this manner of a vast amount of organic matter, which in a stream with high banks would have to be carried forward. The great overflow area provides numerous settling and purification basins in the Illinois river. Inasmuch as by far the largest volume of the water at flood time, leaves the natural channel of the Illinois river, and is distributed through a vast area of land, as a matter of necessity, any original sewage from Chicago or remnants of sewage carried by this water must be in a like manner, so distributed and delivered into a condition for purification by sedimentation or oxidation.

4252 I am acquainted with the various lakes along the course of the Illinois river between Chicago and Grafton. Lake Joliet has the general effect of offering a large basin for oxidation and has the effect of holding up the water to some extent for that purpose. It is true for most of these lakes, in a far greater degree than Lake Joliet, which is in a measure hemmed

in and limited in extent. These lakes, extensions and widenings of the Illinois river below Henry and particularly below Peoria and the region around Havana, north and south of Havana, and not in fact for the whole region practically between Havana and Beardstown, these widenings or lakes in the river provide very important agencies in the disposition of organic matter at flood time, and also to some extent at the time of low water. There are a good many dams along the Des Plaines and Illinois rivers from Lockport to Grafton. There is the dam at the end of the main drainage channel, known as the Bear Trap dam, also I believe two dams in Joliet, one at Henry, another at a point below Pekin some distance, called Copperas creek, and further down at La Grange and Kampsville, also one at Marseilles. These dams in the Illinois river are extremely important factors in holding up the water, retarding its rate of flow, distributing it over a wider area, and therefore of importance in hastening general purification.

4253 They are important because of the effect which I have mentioned, that they serve to distribute the water over a greater superficial area and retard its rate of flow. It is my belief that the Mississippi river at the Illinois shore opposite the Chain of Rocks is not at that point a potable stream and fit for drinking purposes. The Mississippi river was not, at any period prior to the opening of the drainage canal a suitable river for household use. I made numerous analyses of the Mississippi river in years back, prior to the opening of the drainage canal. (Motion to strike out by Mr. Jeffries.)

4254 Because of the addition of a large volume of Lake Michigan water to the canal water flowing down the Illinois, and because further, the increase in the amount of pure water, is very much in excess of the increase in the amount of sewage carried at the same time, the resultant effect is produced that the mouth of the Illinois river today, is in a far better sanitary condition than obtained before the drainage canal opened.

MR. JEFFRIES: I object to the answer and move to strike it out, on the ground that it is based upon analytical data

prepared by the witness from samples of water taken from the Illinois river and that such samples were taken at various times without reference to local conditions, the volume of water, and taken in such a manner as not to be competent, and that in the analyses made by this witness, the volume of water was not considered a source of pollution and the extent of pollution was not considered as an element of the analyses.

4255 Taking into consideration all the conditions which have been supposed and especially the condition of the increased pollution I am still of the opinion that the sanitary condition of the water of the Illinois river at its mouth has been improved instead of injured by the increased flow through the drainage canal. Since the opening of the canal, beyond all possible question the sanitary condition of the Illinois river at its mouth is far superior to the Missouri river at its mouth and not greatly different from the condition of the Mississippi river at a point where the Illinois and Mississippi rivers unite.

(Objection by Mr. Jeffries.)

4256 As I have stated in my previous testimony, I believe the effect of the Chicago sewage is completely lost before the mouth of the Illinois river is reached, and therefore cannot be a factor in determining any pollution in the Mississippi or Missouri rivers. Assuming that the waters of the Illinois river in 1902 were emptied directly into the Missouri river at its mouth before the Missouri enters the Mississippi, the water of the Missouri would contaminate the water of the Illinois, the water of the Illinois being in a purer and better sanitary condition at that time than the water of the Mississippi. (Witness is asked hypothetical question in regard to the depositing of the 107 barrels of bacillus prodigiosus in the drainage canal, etc. This question includes the number of samples of water that were taken at the time the experiment was made and the number of bacillus prodigiosus that were found.

4258 Considering the longevity of the typhoid bacillus as measured by the longevity of the bacillus prodigiosus, which consideration in no way involves a knowledge of bacteri-

ology but simply a knowledge of arithmetic as set forth in this question, I would say that the suppositions advanced in this question indicate that the longevity of the bacillus prodigiousus and the the typhoid bacillus as compared with it, is so extremely slight as to make the probability of a germ of this character being able to survive a passage from the drainage canal to Grafton, so remote as to be entirely unworthy of consideration. This conclusion depends on certain calculations which I have made and which I will present. (Witness shows mathematical calculation from which he deduces the folowing conclusions):

4259 We should find 10,000 bacilli prodigiosus per cubic centimeter at some corresponding time in some part of the river below, but admitting the fact that the change by dilution occurred and that these bacteria were all found in samples collected in a period of four days, I have calculated this original volume of water as diluted with the volume of water which flows at the mouth of the river in a period of four days. On that assumption, a number of at least 200 should be found per cubic centimeter, for each cubic centimeter examined, on the assumption that no death or less of these bacteria takes place anywhere in the course.

4260 As a matter of fact, not 200 were found in one cubic centimeter, but a very large number of examinations had to be made to find a cubic centimeter in which there was one contained. It is evident that an enormous destruction of these organisms must take place between the point at which the bacteria were thrown in, and the mouth of the river where the examinations were made. The actual finding is not over one ten-thousandth of what should be expected from 107 barrels on the assumption that these organisms did not die out; that is, we find less than one ten-thousandth of the expected amount. If we consider a number less than 107 barrels as added, one barrel for example, the probability of any organism of this character

reaching the mouth of the Illinois river is less than one chance in 1,000,000. If we consider one barrel, or one one-hundredth of a barrel as added, the chance of one of these organisms reaching the mouth of the river and being found in a cubic centimeter becomes correspondingly reduced. Therefore, without involving any question of bacteriology, but simply a question of calculation, it is evident that the probabilities of any number of bacteria in a given small volume, reaching the mouth of the Illinois river is extremely remote and not one which can be practically or seriously considered.

(Objection by Mr. Jeffries.)

4261 Q. Professor, assuming all the facts to be true in the foregoing hypothetical question, which was first presented to you, and assume that the longevity of a typhoid bacillus is measured by the longevity of a bacillus prodigiosus, what is your opinion as to the probality of a typhoid bacillus entering the drainage canal at Chicago, from the sewers of Chicago, surviving the journey down the Illinois river and Mississippi river to the intake tower at the Chain of Rocks at St. Louis, based upon all the facts contained in the foregoing hypothetical question?

A. Measuring the longevity of the typhoid bacillus by that of the bacillus prodigiosus, from the fact as stated in the question that in the large number of examinations made at Lockport and Joliet and Peoria, no prodigiosus bacteria were found at all, and from the further fact that at the mouth of the river and at the intake tower at the Chain of Rocks, and in the water supply of St. Louis, the small number mentioned were obtained, and none at all in a period before the fourth of December and none at all after the 8th of December, the possibility is extremely remote, and it is practically improbable, that a typhoid bacillus with longevity and virility as measured by that of the bacillus prodigiosus could ever survive the passage down the drainage canal and the Illinois river and enter the water supply of St. Louis.

4262 CROSS-EXAMINATION, by Mr. Jeffries:

I am a chemist by profession and have made a specialty, among other things, of sanitary chemistry, in the last twenty years or more. I was connected in the early 80's with investigations made of the character of the different waters by the National Board of Health. The investigations which I made were on the question of impurities in the atmosphere and the measurement or organic matter in the air.

4263 The greater part of the work I have done in the way of sanitary chemistry has been done in connection with the State Board of Health of Illinois and with the Health Department of Chicago. Part of my duty is the teaching of physiological chemistry to the classes of the medical school at Northwestern University. I have given such instructions over 20 years. I made certain bacterial tests in connection with my study of the Illinois river, which I have distinguished from the bacterial tests proper. In my examination of water, I have made no attempt whatever to go into the question of the identification of bacteria. That is a field calling for the work of a specialist in bacteriology, but inasmuch as certain changes or reactions of a purely chemical nature are brought about by bacteria, I have given some attention to the conditions of such reactions. Those are properly of a chemical rather than a bacterial nature. Certain bacteria have the power of producing certain decompositions, which can also be produced by chemical means. For example, the decomposition of protein matters by bacteria are analagous in many cases to those by chemical reagents, and in such examinations as I have made, I have confined by attention to these reactions in using what are sometimes called methods in water analysis.

4264 In all recent examinations I include these bacterio-chemical tests with the others. These experiments are those in which the action of bacteria are concerned, but I consider them as chemical experiments and not as bacterial. I consider both the chemical and bacterial tests of importance in such work, but it would be impossible to state which has the greater

value. I think both lines of investigation should be considered.

4265 In some cases that I now recall, the evidence of the bacterial examinations that I made is sufficiently definite to lead to a definite conclusion without appeal to the result of the chemical analyses. For example, in comparison of the Missouri with the Illinois river in 1901 where the bacterial evidence is very strong that the Missouri is a more contaminated stream than the Illinois, I mean the bacterio-chemical evidence as it appears from the purely chemical reactions, brought about by the micro-organisms, the production of indol and the liberation of acid and the coagulation of milk. I cannot determine from a chemical bacterial examination whether or not the pollution spoken of is sewage pollution or from other sources. I cannot tell from my examinations whether or not the bacteria which I discovered are harmless or not. I am not a bacteriologist and can answer no questions involving expert bacteriological knowledge. I do not consider any river water receiving organic matter or drainage of farms or towns as at all suitable for drinking purposes directly. I have not stated that from my chemical bacterial analyses of the water that the pollution is such as to make the water unhealthful.

4266 Q. So your testimony in chief upon the sanitary condition of the water was not altogether based upon the chemical and chemical-bacterial tests that you made of that water, but also in connection with your general opinion upon the sanitary condition of river water?

A. In general, yes.

Q. What is the source, Professor, of the most objectionable contamination of river water?

A. Well, that is a complex question, very difficult to answer in brief terms. The answer to that question would involve a theory as to the origin of diseases. I am not attempting to testify at all as to the origin of infectious diseases, and therefore cannot attempt to tell what is the most objectionable con-

tamination in water. It calls for a kind of knowledge outside of my special province.

4267 I am familiar with what is generally stated by sanitarians as the most objectionable addition to be made to river water. I concur in their opinion in a general way, that is, that certain products of human or animal excretion are the most objectionable substances in water for consumption. I think some scientists agree on the origin of diseases, and on such points in which they agree, I should concur naturally with the belief held in general.

4268 The most harmful source of pollution is that coming from animal excreta. It is measured by the character of the refuse or matter thrown off in this excreta and by the large number of micro-organisms which may be detected by chemical-bacterial tests which I have described and by the relatively large amounts of certain nitrogenous constituents recognized in the chemical tests. There is no way of always determining sharply the origin of all bacteria but where enormously great numbers are found in sewage, from the known facts regarding the production of these substances, the conclusion is, in general warranted, as to where they come from. The general fore-knowledge has to be taken into consideration in reaching a conclusion. In the case of water flowing from a swamp and containing the sewage of some city, it would not be possible to determine the origin of the pollution in most cases. It can be determined only sharply in the case of very strong fresh solutions of either the sewage or vegetable products found and from the decayed or vegetable matter. It is shown by both the chemical and bacterial tests to some extent.

4269 (States how the distinction is made.)

4270 (States the sources of information used in chemical-bacterial tests to assist in determining the source of pollution.)

4271 It is always desirable of course in drawing a conclusion from such examinations, chemically and bacteriologically, to have as much knowledge as possible of all the conditions

that obtain in any stream in question—all possible factors should be taken into consideration in reaching a conclusion.

Q. Now, what are the most important conditions of that stream?

A. Well, the character of the watershed—what is called the watershed, the tributaries in the watershed, the character of the water in these tributaries, the abundance of salt deposits for example, as contributing to the main stream or the tributaries, and many factors of this kind which it is always desirable to have in reaching a final and fair conclusion.

Q. Now, can a fair conclusion be reached without that information?

A. I think it would be unsafe in most cases to draw very sharp conclusions without more or less of this information. (See pages 4263 to 4274 inclusive, for information as to what are the essentials in determining the polluted condition of water.)

4274 I have been familiar with the sewerage system of Chicago since 1886. (States the leading features of that system during the period since 1886.)

4276 The Calumet district empties into the lake. Recent legislation will bring it into the Sanitary District. If the whole territory, including this Calumet region were brought into the district it would add above 250,000 to the present population draining into the canal.

4277 It is expected to include sooner or later the district north of Chicago, so-called Evanston, or the North Shore district. At the present time about one-fourth or perhaps a little less than one-fourth of the population of Chicago drains into the lake and the rest into the river. The population of the district now is not far from 2,000,000, somewhere in the neighborhood of 1,600,000 people drain into the river. Because of the flat character of the city of Chicago, the time consumed in the flow of sewage through the sewers is comparatively large, as compared with the time in most of our American cities; the sewage remains a comparatively long time in these sewers.

4278 In general the condition of the Chicago river in this period from 1886 to 1891 has been bad. It has been foul, and there have been perhaps two general kinds of changes taking place here. There has been an increasing amount in general of sewage going into the river, and an increasing amount from the population, and an increasing amount probably from the stockyards. In my testimony, I explained that while there has been at the same time an increasing effort made to retain this filth in the stock yards because of its commercial value, so that it is impossible to say whether much more or much less has found its way into the river. But this, in general, may be stated as now true, that whereas in the former conditions, rather large amounts of insoluble substances, or floating substances found their way into the river, at the present time practically only that escapes which cannot be precipitated or separated by pressure, or by retarding the flow by means of weirs or dams in the sewers. In general, those extractive matters only which are not easily retained are now allowed to escape from the stock yards. Practically all of the fats and insoluble proteids are retained because of their commercial value for fertilizers or other purposes. It would be difficult to say at the present time whether there is more or less actual matter coming from the stock yards than was the case some years ago. The flow of the Chicago river was somewhat uncertain. Still, in general, it was to the west and south. That is this was maintained by means of the pumps at Bridgeport. In flood time, at the time of heavy rains, the flow was very often reversed, and went toward the lake. Sometimes the condition appeared practically stationary, no current could be observed. At other times it was perceptibly more to the south, and at still other times, to the lake. That occurred at intervals of heavy rains. Of course in the main the flow was through the canal. It was south and west. At times of heavy storm for a day or so perhaps, 24 to 48 hours at a time, the current might be in the opposite direction.

4279 Subsequent to 1900 the flow has been to the west and

south and not into the lake. From 1891 to 1900 at several periods of short duration each, the flow was out toward the lake, in the rainy season of 1892, for example, there were a number of days when the flow was toward the lake. During the times of these reversals, I made analyses of waters in the lake. These samples were taken about a mile from the mouth of the river and up and down the shore.

4280 From 1886 down to January, 1900, the Chicago river would be considered a very foul water. At the present time the south fork of the south branch is rather foul. The north fork is in general in very much better condition than the south fork of the south branch. The longest series of examinations that I made of the water of Lake Michigan was beginning with 1885, but I made occasional examinations down to about 1900. Since then I have made some more. By far the greatest number of these examinations, at least the recent ones, were published in the reports of the Illinois State Board of Health already considered here.

4281 From my examinations I concluded that in time of flood water some of the pollution of the lake came from the Chicago river. These evidences of pollution existed in the waters taken at Lake View tunnel, Chicago Avenue tunnel, the Four Mile tunnel and from the Hyde Park tunnel, that is, from the four main supplies of the city, have shown a slight increase in these factors. At times there has been apparently a very considerable increase in these factors, and false conclusions have been drawn from observations made at those times. It is now well known that there have been several periods when the water was assumed to come through the tunnels when it was pumped from very near the shore. For example, in 1892, when very erroneous and widespread conclusions were published regarding the source of typhoid fever in Chicago, when it was assumed that the waters were all drawn from the long tun-

4282 nels, it is now well known that a large part of the water used on the North Side was pumped from a so-called emergency tunnel, extending out four or five hundred feet in the

lake and ending within the break-water. The engineers, anxious to make a record of economy in use of coal, drew from the short tunnel, delivering a very contaminated supply, and the epidemiologists, seeing the results of this contamination, concluded that the supply from several miles out was badly polluted. At a much later period, which has likewise been very generally discussed, it is known that water has been drawn from sewers in Chicago at frequent intervals. In the matter of discussion why the mortality for certain diseases should be apparently greater in a part of the city which is furnished with the best water supply, this increased mortality having been apparent through a great many years, certain pronounced conclusions were drawn from observations to the detriment of the reputation of the water supplied from the long tunnels. It has since been discovered that owing to very faulty construction in the pumping station, drawing water for one of our supplies, that at frequent intervals in the last thirteen or fourteen years water has been drawn not from the tunnel as supposed, but from the overflow of a sewer into a well in the waterworks, the sewer discharging as much as a volume of ten inches or twice ten inches into the pumping well for hours at a time. I mention this fact because it is to illustrate that it is not always best to draw a definite conclusion from the result of analyses of the Chicago water which came through the taps. The location of the pumping station which I refer to, was on the West Side, drawing water from the so-called Four Mile tunnel—the Harrison street station.

4283 I made some analyses in 1890 of collections made in the lake two and four miles out, at about the location of the tunnel. At that time the water was very good at the tunnels themselves and there was no appreciable difference between the water taken there and the water taken six or eight miles out. The water at these points (the tunnels) is subject to some changes on account of high winds particularly, when there is always more or less sediment washed into the water and stirred

up even as far out as the intake of the two four-mile tunnels.

4284 At times of high water the lake water appears somewhat turbid. This turbidity is caused by the deposit of a large amount of substance—a large amount of clay from the construction of a tunnel under the city having been dumped into the lake, also in building one of the parks a large amount of street sweepings has been dumped into the lake at a point largely enclosed by a breakwater. The tests which I mention indicate the presence of this clay substance which I think is mainly responsible for the opalescent condition which is very frequently observed now.

4285 This was not observed in former years. In my earlier examinations of the water of Lake Michigan the water was very clear most of the year. The water at the intakes at the entrances of the tunnels I consider in the main, generally potable. It would hardly be fair to say that it should be considered absolutely safe for drinking purposes at all times. In reaching this conclusion I consider my own analyses. I depend to some extent also on the opinions of those who are making investigations in other lines, bacterial tests proper. They have some weight in influencing me.

4286 Q. Now, do you take into consideration in passing judgment upon that water, its effect upon the people who use it?

A. I will have to answer that question in this way. Inasmuch as it is practically impossible to determine the effect of the real Lake Michigan water on the people who are using it, or supposed to be using it, I am inclined to depend very little on the stated effect. So little dependence do I place on the statements of the epidemiologists and etiologists that I use and have used, without boiling, Lake Michigan water for twenty years.

Q. Did you ever have typhoid fever?

A. Never, sir, and don't expect to.

4287 Q. Then you discredit the reliability of the effect of the

water upon people who use it as being any indication whatever of the sanitary condition of the water?

A. No, that is not what I said. I discredit the assumed effect of the Michigan lake water on the people of Chicago, since it has been determined that many of the conclusions have been drawn from, not lake water, but from the sewer water, water pumped almost directly from a sewer. The most weighty and unsound conclusions ever drawn were drawn from water collected in that way. A difference is made between a polluted and an infected water, but not chemically.

4288 A polluted water is one which may contain foreign substances while infected water is one which contains or is assumed to contain the elements of disease. The sources of pollution in water are the adding to the water of trade wastes, household wastes, sewage and practically everything which does not belong in a normal water. The sources of infection I can speak of only in a general way, as I am not an etiologist, a bacteriologist nor an epidemiologist. Infections come from so-called pathogenic bacteria, about which I am not testifying. As a chemist really, in a limited sense, infected water has no meaning to me. As a sanitarian, of course, I should object to the use of infected water.

Q. And you haven't considered that anywhere in your analyses?

A. I have been very careful not to go into a province which is outside of my line of inquiry.

4289 The fact that my chemical analyses did not disclose infected matter in the water does not necessarily mean that no infection is contained in the water that I have analyzed. From the analyses that I have made I cannot determine whether there is infection in the water or not.

Q. Professor, are all pollutions equally dangerous?

A. No, in general, it would be safe to say not.

Q. Of what benefit then is the chemical analyses of the water which you have examined, and which is represented by the tables which you have introduced in evidence here, in de-

riving knowledge as to the sanitary condition, or information as to the sanitary condition of the water?

A. Well, this chemical knowledge, combined with the knowledge of the origin and sources of the waters in question, permits a comparison to be made between the different waters as to the amount of their pollution. The work is of comparative value.

Q. Then as a chemist, any conclusions as to the sanitary condition of the water from the chemical analyses that were introduced by the tables here, would be unreliable, would it not, so far as infection is concerned?

A. That does not follow, because we must call upon our practical knowledge and practical experience regarding the sources of water, as we know that infection in the general sense of the term cannot and does not take place in water except by the addition of something else, which the chemist can recognize and does recognize. These tables then have some value in measuring the relative danger or the relative safety of water.

4292 I will admit that sanitarians regard certain diseases as water-borne and in some cases where the weight of evidence seems to be very great, I am inclined to accept the opinion of sanitarians without advancing an original opinion of my own on the subject. In determining the condition of the water in the Illinois river, I depended almost solely on the information afforded by my own experience—my own examination of a chemical nature, and what I spoke of as bacterial chemical experiments. I did not take into consideration infection as I have said repeatedly this morning, and I did not take infection into consideration as to the Missouri or Mississippi rivers.

4293 In forming my conclusions I have left out of consideration the question of infection, because it does not come within my province of discussion. I cannot agree with the assumption of counsel in the question that that is the only point of importance to be considered here. I differ from that very

decidedly and strongly. For the purpose of the examination that I have made it is not the most important at all. The object of all my investigations has been to determine the extent and rate of destruction of organic pollution in the waters in question and to compare these several waters with each other.

4294 I have declared that in my opinion, none of these waters under consideration are safe to drink, because they receive a large amount of filth of all kinds from innumerable places and whether there is any infection or not, I object to the drinking of such waters; that would include Lake Michigan in case it received an amount of filth at all comparable with the waters in question, which it does not. I still prefer Lake Michigan to Illinois river water as drinking water, even since the canal has been opened. It is not possible to assign a hard and fast rule as to what amount of polluted matter in any water would be necessary in order to make it undrinkable and I should not be drawn in any such discussion as that.

4295 If I should find five parts of albuminoid ammonia per million, in Lake Michigan, I should certainly be afraid to drink it. I have never found one part per million. If all organic pollution consisted of dead and not living matter, the water containing any of it would not at all times be specifically injurious but under many circumstances it would be. A great many kinds of dead organic matter are of such a nature that when taken into the human stomach they would interfere with the natural and necessary and normal processes which go on. There are some of them acting as toxins or poisons, and thereby interfering with normal processes; others because of a sense of disgust which they may arouse, so influencing the normal functions that they will not take place in their usual manner. Dead organic matters of these kinds, and products from dead

4296 organic matter may be in themselves then harmful and injurious from the reasons which I have just given. In sufficient amount they would undoubtedly kill people. The chemical analyses would not enable me to differentiate between dead and living materials, or dead or living organic matter in

the water, but the bacterial chemical tests which I have made indicate the presence of the living organic matter as I have explained on several occasions. Most waters contain both vegetable and animal matter.

Q. But you cannot detect it from the chemical analysis?

A. Chemical analysis would not; that is chemical analysis as ordinarily made would not. I would not like to give a perfectly sharp answer to that, because off-hand I do not want to attempt to limit the power of organic chemistry in detecting certain things.

4297 In presenting my opinion, I make practically no use of the assumed experience of epidemiologists.

Q. Professor, as a chemist, are you able to differentiate between organic matter that comes from human excreta and that which comes from street washings, barnyards, cat-

4298 tle pens and other places of like character,

A. No, as a chemist, I should not attempt to make any such differentation in the course of water analysis. In forming my conclusion, or in stating my conclusions, I will say that I have not attached much importance to the opinions of epidemiologists, but have in the reports which have been published, referred to the work of others who have made parallel investigations and who will testify when the time comes, whose investigations were made parallel with my own and on the same waters in most instances.

Q. You have never investigated the relations of health and water here at Chicago, or anywhere else, have you, Professor?

A. Not in a very extended way, but far enough to show that the assumptions made by certain epidemiologists who claim that they have made studies of the water supply of Chicago at several periods in the history of Chicago, but not founded on sufficient knowledge of the facts to merit the attention which the publications really attracted.

Q. Now, Professor, will you state the reason why you have thus concluded?

A. I stated yesterday in some detail, one of the main reasons for my lack of faith in the opinions advanced by these infant industry scientists called epidemiologists. It is well known that in drawing their conclusions these people have been so often ignorant of the most important facts in the case, that the conclusions are finally of no value. From my own studies and investigations and from my knowledge of things as a citizen of Chicago, things which I have paid close attention to for over twenty years, I am able to state positively that in several of the most noted of these cases where epidemiologists from abroad have passed on the condition of affairs in Chicago, they were certainly mistaken in their conclusions. For instance during the World's Fair, when a good deal was said about the infection of Lake Michigan water, a good part of the supply in
4300 one section of the city was drawn not as was supposed—from the Chicago Avenue tunnel, extending out about two miles, but from a short, or emergency inlet—a short tunnel extending out to a distance of about 500 feet, to be used in case of emergencies, in case of a large fire for example. At that time the pumps which were at work in the pumping station at Chicago Avenue, were generally in pretty poor condition. There was frequent complaints of the amount of water which they could pump. There was very frequent complaint of lack of sufficient head to carry the water above the first or second stories of the buildings. At that time in order to lesson these complaints it has been established by investigations, as will be explained, that water was drawn by the engineer in a large quantity and through a very considerable period from the short inlet. This water was very dirty. It was drawn from a point where there was considerable contamination from dumpings and washings and sewers and so on. Therefore I say that the conclusion that the water from the two-mile tunnel was the source of the disease which the epidemiologists described at that time, is not a fair conclusion. At a later period, last year, through the spring and summer of last year, there was a remarkable epidemic of typhoid fever in Chicago. It was a very singular fact—puz-

zling in fact—that the greatest prevalence of this appeared to be in a part of the city which received what was supposedly the purest water drawn from the longer tunnel, and a great deal was written and expressed in public addresses, in regard to the infection of the water at that great distance, shown from the appearance of the fever in this part of the city. It was later discovered, some time in June, I believe, that through some accident or oversight which occurred many years ago—how many we cannot say definitely, perhaps over ten or fourteen years, certainly at a period beyond the recollection of the men employed in the pumping station—a connection was left between a well in the pumping station and a sewer, so that at the time of high water, at the time of heavy rains, it was possible for one of the large sewers in that part of the city to flush over and throw a great volume of foul water through a ten-inch pipe, into this well, so that it could be drawn into the supply. That fact is known to many people in the city and in the engineer's office.

I state that here then as a further explanation of why I
4301 am not willing to accept the determinations of the etiologists and epidemiologists. I am referring principally to people in Chicago who made these complaints of last year, that the source of the infection must be referred to Lake Michigan. It is evident that that was not the source of the pollution in the mains in that part of the city. Those are two and, I think, sufficient illustrations for all practical purposes. I recognize that the relation between the water and the water-borne diseases is a proper subject of study and that certain people are

engaged in this very study and have been for some years
4302 back. I have not tried, from a chemical standpoint, to make it a study because in the employ of the State Board of Health there is a competent bacteriologist and etiologist, to

whom these questions are always referred.

4303 The amount of sewage coming from the stock yards has been greatly reduced in late years since the commercial value of the substances going to make up the sewage has been recognized. Everything is separated in the packing houses

themselves and also to some extent in the big sewer outside, which is the one main which drains most of the packing houses. The amount of substance which actually passes through this Brennock sewer I think I stated was about 90 tons a day of organic matter, through the period of 1899. In 1886, it was about 112 tons daily. The amount of nitrogen corresponded

1304 very closely to the amount of organic matter. On the basis of 250,000 cubic feet of water per minute for 24 hours, this 90 tons of organic matter would make, expressed in parts per million, 90 parts per million of organic matter. For nitrogen it would be about 14, but I would not to put this in as as an absolute calculation until I look it over.

1306 I have stated that in 1890 and 1891 I estimated that five-sixths of the sewage in the stock yards refuse entered the Chicago river and passed into the Illinois and Michigan Canal.

1307 That estimate was made by comparing as well as possible the amount of matter contained in the water west of Bridgeport, that is, the pumping station, with the amount discharged as near as I could estimate it, from the stock yards and other sewers. The investigations were made largely, as I now recall them, in the fall and winter of 1890 and 1891. 130 examinations were made. The larger part were concerned with the stock yards sewage itself. (Witness states how stock yards' examinations were made.)

1309 When a freshet happened, it did not flush out all the sewage that had been deposited in the Chicago river. This freshet from the Des Plaines would carry out practically only that part of the sewage which was in the south branch between the main river and the pumping station. This Des Plaines freshet would not affect the north branch or the part of the south branch south of Bridgeport. Freshets have very little effect on the north branch. I have seen the Bridgeport

pumps many times during a period of ten years. There was no subject in Chicago more frequently discussed and on which more varied opinions were given than on the capacity of the Bridgeport pumps and it would be foolish for me to attempt any accurate definition of what they did. The remaining one-sixth of the polluted matter that entered the Chicago river in 1890 and 1891 but which did not enter the Illinois and Michigan canal was destroyed by decomposition and through bacterial agency.

4310 At times a portion of the sediment must have found its way into the lake. From 1886 to 1900 I am not able to make any definite statement as to the condition throughout all of the river, but in extreme south part of the river there was always a very considerable collection of sediment and in certain parts of the north branch. There were changes going on all the time in the river as in all streams with large amounts of organic matter in them. There was constantly arising foul and putrid gases from it during that time. I always believed that gas refuse had something to do with the odor of gas in the river.

4311 Prior to the opening of the drainage canal, some of the conditions for decomposition in a part of the Chicago river, were doubtless somewhat better than after the opening of the canal. They were better in this particular, that since the opening of the canal, in a certain stretch of the river, less time is given for the oxidation or for the completion of these changes than before. I have not made any examinations of the water since the opening of the canal.

4313 The source of pollution entering the Illinois and Michigan canal since July, 1900, is, as before, the combined house and general industrial and stock yards sewages.

4314 It is very difficult to give a sharp and definite answer as to the flow in the old Illinois and Michigan canal. In 1900 the flow was assumed to be about 50,000 cubic feet per minute. It is generally believed and I have used this acceptation in my experiments, that the flow was nearly 35,000 cubic

feet per minute. In the main drainage canal the flow is approximately 250,000 cubic feet per minute. As to the conditions for the purification of the water in the Illinois and Michigan canal in 1886, my recollection is that the experiments showed
4315 a nearly complete destruction of the organic matter or the breaking down of the nitrogenous products. The loss of organic matter was very marked between Bridgeport and Lockport. This reduction being shown particularly in the change in the free ammonia to the albuminoid ammonia and also in the oxygen consumption, the amount being reduced, the amount as indicated by these determinations being reduced to one-half of what we had at Bridgeport. In 1899 at the same place, and for some reason which I am not able to assign in detail, practically no change in the free ammonia, the albuminoid ammonia or the oxygen consumption was observed between these same points—Bridgeport and Lockport. I know of no conditions positively, nor have I any definite knowledge which would account for the difference in the purification observed in the Illinois and Michigan canal from the analyses of 1886 and those of 1899. I should regard the sewage matter from Chicago in its original condition as detrimental to the quality of any water supply with which it was mixed.

4317 When I stated that in my judgment the sewage matter from Chicago was not injurious to the water supply of St. Louis, I was relying upon the purification which takes place enroute, and assuming that that purification is of the kind and extent such as has been shown by my analyses. These analyses cover all of the conditions which I considered necessary to reach the conclusion expressed. They cover some periods of high water, probably not the maximum or excessive floods. To some extent they cover cold weather periods also. In the recent analyses I don't recall that the river was frozen over when samples were collected, since the canal was opened. I don't know that it freezes over.

4318 No investigations were conducted by me personally throughout the whole year.

Q. Professor, if a very marked purification was obtained in the Illinois and Michigan canal in 1886, and practically no purification in 1899, the conditions remaining the same, is it not possible that the conditions of purification as you have observed them since the opening of the drainage canal—since the drainage canal has been in operation, have been at times changed in some way, unknown to you, so that the water has passed down the Illinois river with a lack of purification corresponding to that which you observed in the Illinois and Michigan canal in 1899?

A. No, I would not be willing to admit that in general, because in leaving the Illinois and Michigan canal, the disturbing factors which interfered with the oxidation in 1899, have evidently largely disappeared, because of the observed fact that the oxidation has gone on further down. The pouring in of this canal water, in which the oxidation in that later of second period, was very much retarded, into the river below apparently restored the conditions of oxidation, so we find a better effect below than would be pre-supposed from what we observed from the canal itself. Hence I would not like to conclude, or would not conclude that there might possibly be conditions interfering with the oxidation in the whole river below.

4319 I make positive statements only about the periods which I have covered in my investigations and where I speak of other times at all I only speak from analogy with those that were in existence at the time I made the examination. I have not made examination as a sanitary chemist of the condition of water in any river when it was completely frozen over with ice.

4320 In general I would consider the question of temperature and all questions of the exclusion of air by ice, as having some bearing on this question. It is in general true that the changes which we describe in broad terms as oxidation are more characteristic in the summer season than in the winter season.

The investigations made in the early part of 1900 I think came nearest to the observation in flood period.

4321 The high water did not continue through the entire series of examinations that I made at any one particular period. The samples were not taken during any of those periods for the purpose of determining the conditions that existed all along the river during that flood period, following the flood from its source to the mouth of the river.

4322 I did not and have not said at any time that the water of the Illinois river at its mouth at Grafton could be considered as a good suitable water. As to the second part of your question, whether this water is less pure in the colder season than in the warmer season, as measured by these several factors, I would say yes. They indicate a much less degree of oxidation in the colder weather than in the warmer times, but at no time would I consider them good, wholesome, safe waters. The degree of purification in February and March of 1902 as compared to the results shown from the examinations made in the summer of 1901 as measured by the oxidation of ammonia is decidedly less, but free ammonia when it appears is one of the last stages in the oxidation of organic matter. The main stages have been long past.

4323 That condition is reached largely by one portion of the substance in sewers before it reaches the outlet of those sewers. One of the common products in sewers in urea, which represents a very large fraction of the excretion of human urine. Urea is a body which undergoes hydrolysis very rapidly, and it breaks down, yielding ammonia, and therefore ammonia does appear early in the sewers. I do not know absolutely what time the ice breaks up on the lower Illinois river.

4324 From my recollection of 1899 and the summer of 1900, the seasons were pretty dry and the water relatively low, but as to whether there was extreme low water or not I cannot say.

4325 Q. Is there any way to determine from the standpoint of a chemist whether the pollution in the Illinois river at its mouth is sewage pollution or pollution of some other character?

A. I should not attempt to make any such characterizations there. In general I should object more to the water from a sewered region than the water from an uninhabited region.

4326 The Missouri is usually a very much greater volume than the Illinois, both receiving large amounts of organic filth. I should consider from general knowledge of the situation a part of the organic matter discharged at Omaha, Council Bluffs, Kansas City and other points as very objectionable. As compared with the pollution of the Illinois river by Chicago, and most especially by Peoria, I consider the pollution from the household waste and stockyards industries of Omaha and Kansas City as small, comparatively, or relatively smaller than the amount of pollution from these places, but it is still large. From these sources it is considerably smaller than the original discharge at Chicago. As a sanitary chemist I should feel that the discharge of the sewage of Omaha into the Missouri river and coming down very rapidly in a swiftly flowing stream, would be a factor to be considered as affecting the sanitary condition of the water of the Mississippi river at St. Louis.

4327 As I just stated for the Missouri river, the discharge of the sewage of Chicago into the Illinois river would be an extremely important factor to be considered in forming any opinion regarding the purity of the water at the mouth of the Illinois river.

Q. And for the same reason it would be an important factor for St. Louis?

A. It would be a factor to be considered in any case.

Q. Now what is your opinion as to the strength of that as a factor.

A. From the tables which I have presented, and from the

curves which I drew, illustrating some of these tables, I made the statement that I believed the pollution from Chicago is the least important, and a comparatively unimportant factor in any residual pollution left at the mouth of the Illinois river.

4328 All these things are factors to be considered of course, but I stated further that the determinations made through these investigations, show a larger amount of organic matter as measured in the usual way at the mouth of the Illinois river, than can be well accounted for by the contribution of the tributaries and the contribution of Peoria, so that the Chicago contribution is completely covered up and lost sight of and minimized as compared with the other. I would say decidedly that there is not more known harmless organic matter in the Missouri river than there is in the Illinois river. We have no proof that the products of organic decomposition left in the Missouri river are any less harmful than the decomposition left in the Illinois.

4329 Well, there is a great deal of nitrate in the Illinois river, more than in the Missouri river, which simply indicates this, that there is a larger amount of nitrites in that form which has yet to be oxidized, whether that nitrogen came originally in ammonical form, or from the nitrate form, we are absolutely unable to determine. In drawing a conclusion from the observation of organic matter I should want to know—as I explained yesterday, that a chemist should know, in all cases—something about the original conditions along the river giving rise to this organic matter. I know about the source of the organic matter in the Missouri and Illinois rivers. I should consider the comparison a perfectly fair one. The organic matter left in the river is in itself harmless. That must be admitted. The organic matter as such is harmless in its advanced stage of decomposition. The comparison therefore is a fair one. It is harmless as far as chemical tests show and undoubtedly as far as any test can show, that this residual organic matter must be harmless in either river; that is as far as its capability of

producing disease is concerned. It should be condemned for drinking purposes because I have stated in general that I should condemn water containing any large amount of substance other than water for the reason that along with this organic matter other things may enter which are not harmless. This organic matter of course supports a certain amount of organic life which I object to. I object to that from the opinions of the class of sanitarians referred to who have worked modern theory of diseases, (I cannot give an original opinion) that some of these living forms of organic matter are the important agencies in the production of disease; that is, I borrow from the knowledge of others in coming to a conclusion regarding the harmfulness of the living organic matter. I take that into account as a factor in comparing the waters of the Illinois river at its mouth with those of the Missouri at its mouth. I referred distinctly in my statement yesterday to the fact that the determinations measuring what is called the bacterial contamination in the mouth of the Missouri are more pronounced than those in the mouth of the Illinois. By bacterial contaminations I mean the presence of those organisms which are able to decompose complex nitrogenous matter, break down complex nitrogenous matters and yield the aromatic compound or substance known as indol, that very long experience has shown to be a reaction produced in waters by certain kinds of bac-
4331 teria, a reaction which, however, can be brought about in laboratories by other agencies. In addition to this, we include in this pollution all those substances or bodies which are able to decompose carbo-hydrates, with the liberation of acid, which is recognized in turn by its power of coagulating milk. If, therefore, we expose milk to the action of water under proper conditions, the speedy coagulation of that milk points to the presence of a relatively large number of these micro-organisms which decompose the sugar in the milk and liberate the acid, which precipitates the casein of the milk, and further, in addition to that, we detect the presence of these micro-organisms by the activity of the liberation of certain gases,

when the water is mixed with a solution containing a constituent which the bacteria will decompose with the liberation of gases. Certain carbo-hydrate substances are decomposed by the bacteria yielding several gases, particularly carbonaceous gases, carbondioxide gas, some of them cause even the liberation of methane. These factors are pronounced in the Missouri river, more pronounced there than in the Illinois river. These things simply point to the presence of a certain kind of pollution, the presence of certain micro-organisms which may or may not be pathogenic. I pronounce no opinion on that. Ammonia and albuminoid ammonia indicate an original pollution with, at some time, nitrogenous matter of some kind. What, I will not attempt to say. The oxygen consumption reaction indicates also the presence of organic matter in the water, because we know from long experience that the mineral substances in the water are not able to bring about the production of permanganate in this way.

4332 I will say in general that I cannot draw any very sharp conclusions from the above as to the character of the pollution contained in the water.

4333 I don't know that any micro-organisms ever get to Grafton from Chicago. I should judge from these reactions that there are micro-organisms there but whether they are Chicago micro-organisms I don't know. There is no way of making such determinations from the standpoint of the science of chemistry and bacteriological chemistry. In general it is true that there is a greater degree of reduction of micro-organisms and pollution in the summer time than in the cool seasons of the year, but the bacterial chemical tests at the mouth of the Illinois river at Grafton in the cool or colder seasons (February and March, 1902) do not show a markedly greater or appreciably greater contamination than during the warmer sea-

4334 son. The presence of some of these bacteria is suggestive of the presence of substances which are widely decomposed, or greatly decomposed. We have nothing present which can yield indol, and the bacteria which thrive on these matters so

decomposed, therefore, tend to disappear. Now, the fact of the absence in general of these bacteria at the mouth of the Illinois river, is a very strong suggestion of the breaking down of the original protein matters beyond that stage where such bacteria thrive, certain bacteria thriving, as we know from chemical experience, on original protein matter, or protein-like matter not far removed from the original protein matter, either on original protein molecule or the albuminoid molecule or the peptone molecule derived from it, but as we continue disintegration, or breaking down of these molecules, we reach gradually bodies which will not support certain kinds of bacterial life, that is, where the original proteins can support certain kinds of bacteria, the more advanced products of the decomposition of this protein cannot. The absence of these bacteria then, through the investigation made at the mouth of the Illinois river, is a very strong suggestion of the practical absence of that kind of matter.

4335 So far as I know these indol producing bacteria are not what bacteriologists call pathogenic or disease bearing.

4336 (Witness is told to refer to Table No. IV giving result of analyses of water at Grafton in February and March, 1902, and reads the rapidity of the coagulation of milk from certain samples.) I will state that I do not know from what source these bacteria which coagulate milk, come; but since the matter has been referred to, I will state that the Illinois as compared with the Missouri river shows a very much less marked indol reaction in the Illinois than in the Missouri. We have production of indol twice in thirteen cases in the Illinois, while we had six times out of eight for the Missouri. The ab-

4337 solutely exact significance of any one constituent contained in the water would be extremely hard to give—practically impossible, but as to whether there is any particular case or instance throughout my whole examination of the water in the Illinois river where any two of these properties enable me to determine the character of the pollution so far as the wholesomeness of the water was concerned, that is fairly easily

answered. I find a certain very large amount of albuminoid ammonia, for example, at Peoria. I can say that the pollution occasioning that is highly nitrogenous. I can say that without hesitation it is more than comes from any ordinary source and I should condemn the water immediately on that determination alone. There is no gradual scale by which ammonia in the water may be reduced until it becomes permissible which will obtain for all waters. We have to judge the waters very largely by what we know of their sources.

4338 I will state as I have said before that I cannot attempt to state exactly the character of the residual pollution at Grafton, whether from two or from all of the chemical determinations I have made. Nitrites in water are not necessarily characteristic of animal or organic matter. The fact that they may come from the oxidation of ammonia or from the reduction of nitrates shows that they cannot be taken as characteristic. They are not necessarily more characteristic of sewage pollution than of pollution of some other character. It would depend very largely upon the drainage area in which the water is found.

4339 Take two rivers with cities situated on their respective watersheds, which discharge their sewage into those rivers and the samples of one water show an average of .034 parts of nitrogen as nitrites, and the other show .0006 nitrogen as nitrites, it would not be possible to draw any very sharp conclusions from such a consideration. The large amount of nitrites in one place you have mentioned, may come from imperfect oxidation of ammonia, but it may come from a reduction of the nitrate already formed, if this nitrate happens to be present with a considerable amount of fresh organic matter, for instance, such as would be left in the stream by the death and decomposition of water plants. We have there a condition similar to that which has been observed frequently by agricultural chemists; there the reduction of nitrates may follow. So far that fact it is very difficult and practically an impossible matter to draw any conclusions from the case you state. If you

eliminate everything from the water of those rivers save the sewage discharges of the cities, my answer would be the same, because the products of decomposition of sewage in some stage may bring about a large growth of water plants which dying off in the presence of nitrates—products of oxidation, would lead to a reduction of these nitrates and a reduction of nitrites.

That is the case any way you look at it.

4340 We do not know whether the condition is one of advanced oxidation or a retrograde change of reduction. If the nitrites were accompanied by very high free ammonia, it might still just as well follow that we have a reduction of nitrates to nitrites in the presence of organic matter. The presence of free ammonia would not interfere with that fact at all. The fact that on the banks of the river is located a large and populous city of 1,500,000 people would have some effect on those results in the way of discharging sewage from such a large population.

Q. Isn't it reasonable to expect from a scientific standpoint that as the population increased, as the sewage discharge from the city increases, that these particular properties will increase and be shown in the chemical analyses?

A. It would necessarily follow that there must be an increase in the products of carbon dioxide in the various amido and aromatic compounds, in the ammonia produced and in the nitrates produced, but of the subsequent reactions between these things themselves, it would be very difficult to say very much from the present state of our knowledge of just how those changes were all brought about.

4341 It is natural for scientists to expect large results in these different properties and forms of nitrites or nitrogen coming from the sewage of a large and populous city. From a large protein discharge we would naturally expect correspondingly large amounts of nitrates, whether it be from the city or the distillery or a cattle shed. Such as, for example, are in the city of Peoria, in the State of Illinois. I believe as a rule, nitrites and free ammonia run higher in the Illinois river

at its mouth than they do in the Missouri river, but it doesn't follow that the Illinois is more polluted than the other streams because the pollution is measured by many factors in addition to these. Free ammonia is considered as a measure of sewage pollution, but nitrites absolutely not, as it has been shown so conclusively by the investigations of agriculturalists that nitrites can come just as well from the reduction of nitrates, as from any other source.

Q. Now, Professor, speaking of free ammonia and assuming that it is indicative of organic matter of animal origin, give me the average amount of free ammonia disclosed by your analyses at Grafton of the Illinois river for the year 1900?

A. For the summer of 1900 we have left at Grafton in the Illinois river an amount of free ammonia measured by .07. In 1901, through the late season, the summer, fall and early winter season, we have .238. During the spring of 1902 we have left free ammonia at Grafton, an amount measured by 1.344.

4342 If, as assumed by the question, the only indication of organic pollution is that of free ammonia, then I should answer affirmatively, that the Illinois river in 1902 in the winter appears to be more contaminated than in the summer of 1900, but as we have other measures of organic pollution besides free ammonia, it would be necessary to consider them before drawing a final conclusion for the whole case. The nitrites increased in 1901 over those of 1900 but there is not much difference, there is a trifle. I could not tell what was the cause of this rise in free ammonia in 1901 over 1900. The large amount of free ammonia in the spring of 1902 indicates a lower degree of oxidation, that we would naturally expect from the colder season. Whether this is due to the great increase of material at Peoria I have no means of knowing, as I made no determination of Peoria at a corresponding time. Assuming that the deposits from the cattle sheds and distilleries of Peoria decreased during the years 1901 and 1902 I would say in general that the oxidation of this factor is not as far advanced

as in the other seasons, that the breaking down of the pro-
4343 teid from the more complex stage, or the breaking down of the nitrogenous matter from the complex proteid stage has apparently gone practically as far, but the oxidation of the ammonia as one of the products of this decomposition has, for some reason been delayed. It does not follow that no correct analyses could be made upon which a credible opinion could be based, unless the analyses be taken for one end of the year to the other. I insist that the opinion I have given can be believed as much for these analyses as for any other. I believe the analyses which I have presented represent correctly the conditions of the river at Grafton at all times of the year.

4344 Assuming that Chicago would grow to sufficient size and proportion from the standpoint of population that its sewage discharged into the canal and thence into the Illinois river would produce the same ratio of increase in free ammonia at Grafton, I would say that it was a very bad water to show such an increase in the amount of ammonia. I believe that in a general way the period of beginning oxidation has been somewhat retarded in the Illinois river by the opening of the canal.

4345 I made an examination of the Mississippi river water above Grafton in the late fall and early winter of 1901 and the spring of 1902, probably 25 to 30 examinations in the fall and 10 or 12 in the spring.

Q. Now, Professor, suppose that you had made a series of analyses of water on both sides of the Mississippi river at St. Louis, for a long period of time, and that you had found that organic nitrogen in its different forms invariably ran so much higher on the Illinois shore than on the Missouri shore, and suppose further that you had also made analyses of the water of the Mississippi at a point above Alton, and of the water of the Missouri river above its mouth, for a long period of time and had found that organic nitrogen always ran higher in the Mississippi than in the Missouri and suppose that you had also made analyses of the Illinois at Grafton, and of the

Mississippi above Grafton, and had found that as a rule organic nitrogen in its various forms was higher in Illinois than in the Mississippi, what would you say as to the effect of the Illinois river upon the water of the Mississippi at St. Louis?

(Objected to by Mr. Todd on the ground that the facts predicated in the question were not based on the evidence.)

A. If I had ever made such analyses and had obtained such results, I should of course be obliged to attribute the high nitrogen in the Mississippi to the Illinois, but I do not believe that such results are found or ever have been found in any such examination in any given period of time.

4346 Eliminating all other sources of pollution of the Illinois river save that caused by the sewage of Chicago, if I found that the water at the mouth of the river disclosed large quantities of organic nitrogen, in excess of that found in the tributaries of the Illinois, flowing through farm lands, tributaries not contaminated to any large extent by household drainage or sewage; then I should say that the organic nitrogen starting from Chicago had not been completely decomposed, but as a matter of fact at the mouth of the Illinois we do not find any such condition, even with everything which is added. At the mouth of the Illinois the condition reached, considering all circumstances, is so close to that found in the tributaries, that the supposition made is impossible. I mean to say that at the mouth of the Illinois river during flood times; times of high water, because of the spread of this water over enormously great area, the fraction of contamination starting from Chicago has been so far reduced by this dilution that any effect which it might have in retarding oxidation is fully counterbalanced by the enormously greater dilution and that condition of the Illinois river so far as the original sewage is concerned I believe is no worse then than at any other time.

4347 Assuming that the land over which there is an overflow in high water was levied, then conditions would be changed and we would find a difficult result.

4348 In determining the aggregate amount of pollution flow-

ing into the Mississippi river from the Illinois at Grafton, I would not consider the total weight in the whole river. That is the least important factor to be considered. If we consider the whole weight of common salt, for example, in Lake Michigan, we would have enough there to poison an army. In the Illinois river we do not care, nor should anybody care what the total amount of pollution is. We are practically concerned there, and in every other case, only with that part which is contained in a given volume.

4349 The increased volume of flow in the river is a very important element. The increased flow in the Illinois river will put 20 times the volume of water at St. Louis than that which was discharged through the original Illinois and Michigan canal; with a dilution of 20 times and no possible increase of contamination beyond perhaps 50 per cent, it is perfectly preposterous to think that there should be a larger amount of organic matter from Chicago in a given volume reaching the mouth of the Illinois under such conditions. In that answer I have taken into consideration the condition of the Illinois river as it existed prior to the opening of the canal and the condition of that river as it has existed since the opening of the canal. I have been familiar with the Illinois for 18 years. I have compared the volume of flow in the Illinois river before the canal was opened, with the volume after the canal was opened, the amount of sewage going into the canal, in the old Illinois and Michigan canal, with the maximum amount which can go into the canal when the proper sewage connections are made in Chicago.

4350 Frequently in the Illinois river, before the opening of the canal, it is a fact that the water was low. At times it was very low; but in those times, however, the Illinois river water received from a source outside of Chicago a very much greater portion of—or a somewhat greater portion of contamination than it does at the present time. The increase of water in the Illinois river has not carried any corresponding increase of contamination from Chicago at all. This increase of

water has not been sufficient to impede in any material way, the rate of destruction of organic matter. As a matter of fact we find today at the mouth of the Illinois river in general a better organic condition than was found before the opening of the canal.

4351 I will say, as determined by my investigations, that the condition of the Illinois river at its mouth after the opening of the canal is very much better than it was before the opening of the canal. It is evident from this fact that the conditions for the destruction, elimination, and reduction of organic matter must therefore be better now than they were in 1899.

Q. Now, Professor, with a slow current, with practically no current at times, with the life period of all bacteria limited, with the period of the breaking up of the solid parts in water limited, I will ask you if it is not more reasonable to believe and if it is not according to the experience of scientists, upon the subject, that the solid matters and the decomposing matter that came from the source of the river prior to the opening of the canal, was more readily removed before it reached Grafton than it has been since?

A. In answer to that question I will say that I base my conclusions simply on the record. I cannot go behind that, the record shows the reverse of what you assume in your question.

4352 Assuming that it will require 20 days for the water in the Illinois river to run from its source to its mouth prior to the opening of the canal and that it requires ten days since the opening of the canal, this time limit can have no possible bearing on the question of the determination of the fact whether decomposition has taken place more rapidly or not, because chemical analysis is made irrespective of the rapidity with which the water comes down there.

4353 Dilution does not necessarily destroy but it renders less

probable an effect in proportion to the extent of the dilution. The effect diminishes as dilution increases.

4354 I have not compared the gross pollution of the Missouri with the Mississippi, or the gross pollution of the Illinois with the Mississippi. I say that for all practical purposes, for the purposes of household use, such a comparison is absolutely valueless and absurd.

Q. But, Professor, you gave an opinion as to the sanitary condition of the water of the Missouri river. Now I want to know whether or not you considered the question of dilution in passing upon the condition of that water. Yes, or no?

A. The question is unfair because as I have stated myself several times, the only practical problem we are concerned with in considering waters, is not the gross pollution in any large amount, as a lake, sea or the ocean, but the pollution appearing in a given volume. It makes no difference what the volume of the Mississippi river is, or the volume of the Missouri, or the volume of the Illinois, or the volume of Lake Michigan. The chemist is concerned therefore only with that amount which one is liable to come practically in contact with in his daily usage as drinking water or for household purposes, and parts per million or grains per gallon or any other unit per given volume is the only thing which a practical man has to take into consideration at all.

4355 I haven't attempted to determine in all cases from chemical analyses alone the sanitary condition. I believe no chemist would make as broad a claim as that. I do not know what the sewage discharges of Kansas City, Council Bluffs, etc., in fact the whole drainage of the great Missouri valley, with its tributaries entering the river, amounts to, but it is unquestionably large.

4356 As I made no such examinations in giving my opinion as to the pollution of the Missouri river in parts per million, of course I have never considered the amount of sewage flowing in. It would not be necessary to consider it; I know it is there. In expressing results in parts per million, dilution is

a factor that goes in—volume as compared with the amount of stuff present. The dilution factor enters right into that opinion every time it is given. My opinion regarding the Illinois river as to dilution is based on my experience as an analyst. It is based further on my experience as a pretty close observer extending back through a period of 18 or 20 years.

4358 In my opinion, the sanitary condition of water can be determined by chemical analyses of that water, regardless of the source of pollution or drainage territory of that river in numerous cases. As an example, if I should be sent a jug of water taken from the river at Joliet and analyzed it, I could determine in one-twenty-fifth of a second that that was pretty poor stuff to use. I would not recommend it for household use. If I were to be sent a sample from the Mississippi or the Missouri without knowing anything further, I should not be inclined to give a very definite opinion on the results of one examination, and should not. If I were sent a sample of water with the statement that that water flowed through no natural salt beds, the soil of which was not of a saline character and that the sample so analyzed would disclose from 12 to 15 parts per million of chlorine, I would say that it contained so much salt, that is all I could say. I could not express an absolutely definite opinion as to the source of that salt, but I should be inclined to think that it had been exposed to some organic contamination somewhere, if all the assumptions in the question were correct. The presence of the chlorine however, does not necessarily imply the absence of deleterious matter. I suppose most of the water that passes through the canal and enters the Illinois river at its source, reaches the Mississippi river at the Chain of Rocks, subject of course to evaporation and absorption. When that water reaches there it is necessarily diluted. The only constituents of the sewage of Chicago which would remain with that water in its journey down the Illinois river would be the mineral or organic. They are the only ones of which we can say with certainty that they must remain largely, or in the main.

4360 The organic bodies are those on which the bacterial destructive processes are carried on. These are the substances which are changed and altered and in many cases absolutely destroyed. These processes change the form and change profoundly the character of the organic matter. I think beyond all question there must be some organic substances of stable type which remain for long periods unchanged in natural waters. What these are it would be very difficult to say.

4361 We cannot determine whether they are living or dead organic matter but the so-called bacterial-chemical test would give us an indication of the presence of living substances.

4362 Q. Then if I understand you correctly it is possible that some of the residue and bacteria from Chicago deposited in the Illinois river, remain with that water until it reaches the Chain of Rocks?

A. You have involved two assumptions in your question which do not at all go together. While it is possible that the ring structure residues may remain, which bodies are of a remarkable stable character, it would not follow that bacteria leaving Chicago would exist one one-hundredth of the time or distance.

4363 It would be perfectly absurd to assume that because various stable bodies can pass down the river that the very unstable substances should likewise be able to pass down the river.

4364 Inasmuch as in spite of all the investigations which have been made no one as yet has found a disease germ passing from Chicago to St. Louis, I do not believe that a disease germ would pass.

4365 As a chemist pure and simple I do not know that these diseases producing materials or substances of a living character do not pass from Chicago to St. Louis, but I am not aware that any one has ever discovered their passage. Inasmuch as through these investigations they have not been discovered, I am justified in taking the position that they are not

there. Not being an etiologist or bacteriologist, I cannot speak from that standpoint but from the standpoint of an educated layman I should think the probability of death and destruction following in St. Louis, the detection of one typhoid fever bacillus, is so absurd as not to be worthy of consideration. 10,000 samples taken in two years, the examination of only one cubic centimeter being made at each time, would be 10,000 cubic centimeters of water. Reduced to gallons this would be something like two and one-half gallons and would be an infinitisimal part, of course, of the water flowing in the Illinois river during those two years. My statement of opinion that there were no typhoid germs in the water, was based on the experiments of others and from the standpoint of an intelligent layman and not of a bacteriologist. After these thousands of examinations have been made and none found, there was no evidence apparently that they were there.

4369 It is my individual opinion as a layman that because out of these thousands of investigations no disease germs have been found, it strikes me as highly improbable that there is any reason for assuming that they are there.

4370 Going back to these live organic substances, following the various specific organic matter found in the waters of the Illinois river and the residue of the organic matter, I would say in general that it does not follow that these small particles of injurious substances that may follow will more readily reach the Mississippi river during high stages of the river than during low stages, for the reason already explained that because of the character of the pollution in spreading out in the waters over the land, the probability of any single thing reaching the mouth of the Illinois river from the drainage canal is correspondingly diminished. While great dilution increases the stream flow it at the same time increases the stream expanse covering an enormous area for sedimentation and settling and loss of organic matter. I have said that a very large part of the discharge from the canal is spread out over a broad area of land upon the river. That part of it is not spread out which

remains in the channel of the river, but at the time of flood this part is but a fraction and even a very small fraction of the whole. The dilution does not necessarily mean the absence of the germ. Whatever matter is there is distributed through a larger volume. Inasmuch as bacterial activity is less

4371 in winter than in summer time, it is altogether probable that the amount of material passing down the river in the colder season, is greater than the amount passing down the river in the warmer season, how much greater I don't know. The characteristics of a septic tank, exclusive of air, is the presence of certain bacteria. The exclusion of air is a vital consideration in certain kinds of septic tanks I believe. I have not testified as a sanitary engineer and do not care to go into any description.

4373 I have some little knowledge about septic operation of the water in sewage in the Chicago river prior to the opening of the main drainage canal. For the purpose of the comparison I have described the conditions in the Illinois river as comparable with those conditions which obtain perhaps more or less perfectly in the operations of a septic tank; I have observed the conditions in the old canal and in the river before the canal was built, and also in Peoria above Pekin, at Wesley, and these conditions seemed to be analogous to those which would obtain in a septic tank. The operations which I have noted at those places are largely the disturbances due to the liberation of gasses and in some cases I have observed also a coating or scum over the water which is described by the people who were in charge of the operation of these septic tanks as a peculiar thing very frequently noticed in them. I do not recall ever noticing anything in the main canal of that character before Joliet was reached, but I have observed after the opening of the canal, the same thing above Pekin.

4374 I observed the important fact of a large amount of filth added at Peoria half way down the Illinois river and it doesn't concern me at all and does not enter into the problem as important whether there is dissolved oxygen there or not. I

would not be prepared to admit that in an investigation of any kind the presence or absence of dissolved oxygen at Peoria, Wesley and the mouth of the river, cuts any figure at all.

4375 I am not prepared to state the amount of dissolved oxygen because as I said several times, I did not determine it, but I am glad it has been determined. In the lower part of the river I have no doubt that the testimony will show it was abundantly present.

I did not take cross sections of samples in the Illinois river at Peoria or at Wesley, but in my examination of the water at Wesley, in company with the engineer of the State Board of Health, Mr. Jacob A. Harman, I spent considerable time in looking at the river and determining the point at which the mixture of the cattle sheds and distillery wastes or discharge, with the river water was practically complete and uniform. We decided finally on a place far enough out to secure what I considered a very fair representative sample, neither exaggerating or diminishing the average condition of purity there.

4376 At that time in 1899 there appeared to be considerable of this operation which I have described as septic, that is the liberation of more or less gas in places, from the river. As I recall now this action was pretty general at a point below Wesley. When I state that I had a fair sample of the water in the river at that point I say so from my observation of the water at that time.

4377 I made no cross-section there. These samples were taken probably a quarter of a mile below Wesley. If the water in the river was in such condition as to be undergoing process of septic operation the current would be relatively smaller than it has been at other times, but the current is still quite perceptible and the amount of these great masses of filth is perceptible. This observation I am speaking of was in 1899. The masses which are locally described as floating islands here.

Q. Do you not maintain, Professor, that while these discharges from the distilleries were lying upon the shore of the Illinois river at Peoria, fresh sewage being continually added

to it, so as to keep it in a moist condition, in a condition suitable for decomposition, that objectionable features of that material would not disappear in part while it remained there on the banks of the river and that the same deposits if carried at once into the river and passing down the river would carry more objectionable qualities with it than it would if it remained on the banks of the river a certain time?

A. If all the assumptions made in the question were true, it would necessarily follow as a matter of course, that this objectionable matter would be further carried down the river, but the assumption does not correspond to the practical case. Going back to my record, on which I must depend, my record of analyses, I find that the reverse of what has been assumed in the question is the actual situation.

4380 I have seen, since the opening of the canal, the same floating islands. It is possibly true that the effect of the opening of the canal has been to hasten them in their passage down the Illinois river. These islands do not flow as such any very great distance down the river. They appear to break to pieces and sink and come up again and eddy about.

4381 I do not recall that I ever saw them any very considerable distance below that location in the river. If I should find that a fair cross-section set of samples was taken

4382 and showed results at the same points different from that of my sample, I should be in duty bound to think that perhaps there was some mistake made in the collection of my sample, assuming all the conditions. But if I have no such evidence that a cross-section was made at the proper point, then I would have no reason to modify in any respect the opinion which I give, based on the evidence of the analysis of the sample at the point where my directions were given to collect the sample. In my analysis I am not concerned with the population of Peoria or the extent of the cattle industry at that place.

4383 In forming my opinion I have taken in consideration the fact that there is a large amount—or there are a large number of cattle fed there, and that there is a very large amount

of grain mashed at Peoria, mashed before fermentation, and that this offal or slop from this in various years has been sufficient to amount to a contamination equal or in excess of that proceeding from Chicago. As the first products of the disintegration of the discharges from the distilleries, etc., at Peoria require a relatively large time for the final disposition, it is my opinion that the discharges from Peoria are probably more important in the contamination of the lower Illinois river than the discharges from Chicago. The discharges from Peoria, consisting as they do largely of material in which the progress of oxidation is very slightly advanced, require a longer time for their final decomposition than would the discharges which would have gone through the human organism and in which the decomposition has been practically completed.

4384 In the fresh mash there is certainly nothing harmful, but I know of no fouler contamination or worse smelling or worse acting putrefying substance than this slop material when it begins to undergo bacterial decomposition. That substance deposited into the Illinois river, consists pre-eminently and characteristically of undecomposed protein substances, and must be considered as far more objectionable than the ordinary agricultural farm washings. I am using that word "objectionable" in the sense of applying to the character of the products as produced from this material in its early stages of putrifaction.

4385 The sewage of a large city consisting in the main of the products of animal disintegration, contain substances which have been largely broken down. (Witness states constituents of such sewage and method of disintegration.)

4386 In the distillery refuse, because we have a very large complex substance there not yet broken down and because they must undergo the first as well as the final stages of decomposition, a very much longer time is required for that decomposition.

4387 If as assumed in this question, in 1900 there was a large

amount of water from tributaries and from rainfalls, in addition to the large amount of water from the drainage canal, and then assume that in some subsequent year we have a very much smaller amount of water from the tributaries of the Illinois, and the same amount of water flowing through the drainage canal, or no increase of water from Lake Michigan through the canal, with the same amount of sewage discharged, it would follow as a matter of course, that in the succeeding years the dilution at the mouth of the Illinois river, as compared with the 1900 period, would be less, making all those assumptions.

4388 If the dilution at the mouth of the Illinois river were allowed to depend mainly on the water of the tribuaries, then there would be of necessity a variation in pollution there, and possibly some variation in the sanitary condition, but if the water from the tributaries becomes gradually a small factor, compared with the great and to be greater flow in the drainage canal, then these variations become of less and less moment in the succeeding years. It is possible that an increase of water might, by hastening the flow, push farther down the point at which oxidation is completed.

4389 If we grant that assumption that the amount of organic matter in the Illinois river is greater now than it was before 1900, then it would necessarily follow, taking in the stream flow also, that the aggregate amount of matter in the Mississippi river must be increased but not necessarily the important factor, which is parts per given volume.

Q. Professor, assuming that the Illinois river exists in its primal condition, with no pollution there either as to human being or as to domestic animals, and that the Illinois river itself exists as at the present time and that the Chicago sewage enters as it now does, into the Des Plaines river and thence into the Illinois river, are you able to state that all objectionable and injurious qualities of the Chicago sewage would be eliminated by the time it reaches Grafton?

A. From the study of all the results of the chemical analyses which I have made of the water from Chicago to Peoria,

and through Peoria and to the mouth of the river, I see nothing in the condition at the mouth of the river which suggests at all that the condition today organically is any worse than that in the ordinary streams of the State, and any worse than that which might have existed in the upper Illinois river. In comparing the Illinois river at its mouth, with the waters of the various tributaries through the season of 1899 and 1900, when such comparisons were made, I notice and have noticed, and have referred to the fact that the peculiar relation of the factors of albuminoid ammonia to oxygen consumption,—in other words the ratio which the factors expressing the albuminoid ammonia, bear to the factors expressing the oxygen consumption, are very similar, practically identical at the mouth of the Illinois river with what we observe in the examination of the tributaries. It is a peculiar and very interesting fact that for the tributaries the relation of the oxygen consumption is nearly a constant value which would be expressed, taking the average of all streams, by .07 about; we find by observing the same relation as I have before mentioned, several times practically the same figure at the mouth of the Illinois
4390 river, while the characteristic figures of waters with known animal pollution or containing essentially animal pollution, show a factor in mean about double this; so from these observations I am inclined to say that as far as the organic pollution is concerned the Illinois river today as disclosed by the analyses I have made—and these are the only things on which I am at the present basing my opinion—is very similar, practically identical with the waters flowing through our State, and taking up a large amount of organic matter from the soil and decaying vegetation. Assuming the conditions mentioned in the last preceding question, I do not undertake to make any positve assertion that any part of the objectionable pollution from Chicago reached the intake at St. Louis but from all the evidence with which I am acquainted I see no reason to believe that any of the original elements of the Chicago sewage have reached the intake of the St. Louis waterworks.

4391 Assuming that all possible sources of pollution are re-

moved from the entire drainage area of the Mississippi river above the Chain of Rocks and that said watershed and drainage area were in their primal condition, the water at the Chain of Rocks would have to be considered suitable for household use. Assuming the same conditions as in the previous question and also assuming that the sewage discharges from 1,600,000 people in Chicago were discharged into the Illinois river by means of the canal as it now exists and the waters of the Illinois river entering the Mississippi above the Chain of Rocks, with such assumption, and the evidence that I have of the rate and conditions of purification in the Illinois river, and with no other discharges into the Illinois river in its course of 300 miles and over, I see no reason to condemn the Mississippi river at the Chain of Rocks, because of the entrance of the sewage of Chicago plus no other contamination, over 300 miles above. From all the evidence in my possession, I believe that none of the contaminating qualities or properties of Chicago would reach that far. I have nothing to show that they do.

4393 I insist emphatically that there is nothing to show that original contamnation from the city of Chicago does reach the mouth of the Illinois river or the Chain of Rocks.

4394 If the assumption be granted, which it is not, that original organic contamination reaches Grafton from Chicago, then I would not be prepared to state that it might not reach the Chain of Rocks.

RE-DIRECT-EXAMINTION, by Mr. Todd:

Under the assumption that the Illinois river was a virgin stream, receiving no pollution or contamination from Lockport to Grafton, except that which enters through the Drainage canal, I do not wish to be understood as saying that any of the original pollution could pass as far in the channel as Grafton.

4395 CROSS-EXAMINATION, by Mr. Jeffries:

4396 My first answer to Mr. Todd, on re-direct-examination I did not mean that the residual organic matter could not be found at Grafton. As I have explained, that residual

organic matter was so comparatively stable that it may pass very long distances in a stream.

F. ROBERT ZEIT, examined in chief by Judge Springer:

I live at No. 4016 Vincennes avenue, Chicago.

4397 Am teacher at Northwesern University Medical school and Post Graduate Medical school of Pathology and Bacteriology. My early education was received in Switzerland and Germany. My medical degree is from the Western Reserve University of Cleveland, Ohio. I was afterwards with Professor Klebs and when he opened his laboratory in Chicago I was his instructor for three years. He is one of the noted bacteriologists. For twenty-five years he was a teacher of pathology and bacteriology, at German, Swiss and Austrian universities, and was induced to come to this country and was here five years in all. He was called to Rush Medical College as professor of pathology. After one year, I was made professor of bacteriology at Northwestern University Medical school and one year or more ago, I was given the whole department of Pathology and Bacteriology. I obtained my M. D. degree at Cleveland, Ohio, in 1887.

4398 I have practiced medicine and surgery about 10 years, partly in Wisconsin and partly in Chicago. I have made special study of the causes of diseases of human beings. I made bacteriological examinations of waters of the Chicago river and Illinois river between February 6 and October 1, 1900. I obtained samples of water from Prof. Long.

MR. JEFFRIES: We object to the answer for the reason that there is no evidence showing that the samples obtained by this witness or any of the samples that were taken out of the Illinois river or the Drainage canal, and no evidence showing that the samples were taken under his direction, or the manner in which the samples were taken.

4399 MR. JEFFRIES: Now I move to strike out all that the witness has said with reference to the bottles received from Prof. Long, for the reason that bottles so received by this witness, as shown by the testimony in evidence, was a limited number, and not such a number as would justify any conclusions as to the sanitary condition of the water in the

Illinois river, and for the further reason that sanitarians are unable to derive any value from the results of a limted number of analyses of any water, and especially water flowing in a running stream, and for the further reason that the evidence shows that the samples so collected were not so taken as to cover storm periods, cold weather periods and all the variations of the river, and the water therein, and for the further reason that the evidence does not show that the samples were so taken as to obtain a correct bacteriological examination of the water in the Illinois river at flood times, commencing at the source of the flood, or the entrance of the flood into the Illinois river and following it to its mouth, so that any analyses made by this witness of the water of the Illinois river would be incompetent,, irrelevant and immaterial and of no probative force.

4400 The tables printed on page 46 and the succeeding pages down to page 62 of the book entitled "Illinois State Board of Health, Sanitary Investigations of the Illinois River and Tributaries, 1901," contain the chemical analyses of similar samples examined by me bacteriologically during that period.

MR. JEFFRIES: I object to these tables for the reason that the original tables upon which the results of the analyses were recorded is the best evidence and for the reason that I cannot cross-examine the witness on the original table.

4401 MR. JEFFRIES: If it be true that the bacteriological tables of this witness were introduced in evidence by Professor Long and so sworn to by him, I move to strike them out for the reasons stated in our previous objection, that we have not been given an opportunity, on account of the failure to produce the original tables, to cross-examine this witness as to the correctness of the entrance made thereon.

The specimens of water which I received from Prof. Long were plated by us. The object of our examination was principally to determine the presence or absence of pathogenic bacteria in the specimen of water submitted. That was our function in the investigation—no other.

4403 We further made a number of animal experiments, with

all the samples obtained, or which were given to us by Professor Long. The experiments included intraperitoneal injections of guina pigs with four cubic centimeters of the water of every station. Another set of experiments with the same waters included the inoculation, also intrapitoneally, with culturs made by adding one cubic centimeter of the suspected water to five cubic centimeters of nutritient bullion and keeping the mixture in the incubator at a temperature of 37 degrees centigrade for 24 hours. Of these cultures, one cubic centimeter was injected intraperitoneally into guinea pigs. The object of the latter experiment was to favor the growth of pathogenic bacteria and keep back the growth of non-pathogenic saprophites and water bacteria. In other words, to enrich the water in disease producing bacteria by adding favorable culture medium and exposing them to a favorable temperature. Disease producing bacteria are favored and multiply rapidly at 37 degrees centigrade, whereas water bacteria would be somewhat held back by such a temperature. The culture thus enriched in pathogenic bacteria was injected intraperitoneally and when the animal died, cultures were taken from he blood, the heart blood, the spleen and lymph glands. Also smears were made at that time, and a diagnosis as to the disease and the organisms causing the death was attempted and made in most of the cases.

Q. Please state, Professor, in detail now, the results obtained by the various bacterial examinations which you made, the number of examinations made of the waters of each place, indicating the number of bacteria, pathogenic and non-pathogenic, found, and what tests were made, if any, to determine the number of pathogenic bacteria that may have been in the samples?

MR. JEFFRIES: Objected to for the following reasons. Witness has not produced original table from which these results were recorded and therefore counsel for defendant have been denied the privilege of cross-examining witness on the correctness of said tables. That witness is reading from report of State Board of Health. That that part of report
4404 which he is reading from shows that no sufficient num-

ber of samples was analyzed by him and his assistants to determine the correct character and state of the water in the Illinois river at the various places where the samples were taken, nor do these samples display the correct bacterial character of the Illinois river at flood times, at winter times, at low stages, at high stages, nor are any floods followed from source to mouth. That samples were so sparsely taken and so few examinations made that no expert would consider them of any importance in passing upon the sanitary condition of the water flowing down the Illinois river and the bacterial changes resulting therein.

A. From Lake Michigan tap water found colon baccillus three times. Guinea pigs injected with different specimens of water all recovered. Three guinea pigs injected with specimens containing pathogenic bacteria, only one died of sepsis and the blood of the animal contained bacilli coli com-
4405 munis. Subcutaneous injection caused only a local abscess and the animal recovered. Some of these specimens of water contained a moderate variety of bacteria commonly found in sewage but only one of the samples contained virulen coli bacilli. (Witness gives names of non-pathogenic bacteria found in these waters and the number of times each genius or specimen was found. Examined 13 specimens from Western Avenue, in the new Drainage canal. Gives list of pathogenic and non-pathogenic bacteria identified.)

4406 (Gives list of pathogenic and non-pathogenic bacteria found at Bridgeport.)

4407 The intraperitoneal injection of four cubic centimeters of several samples of water into a guinea pig did not produce death, whereas, one cubic centimeter of a mixture of one part of water to five parts of bullion, kept in the incubator over night at 37 degrees centigrade, proved invariably fatal to guinea pigs in a short time. Even subcutaneous injections of one guinea pig produced a fatal septicemia.

4408 (Gives list of pathogenic and non-pathogenic bacteria found at Lockport.) Injection of four cubic centimeters into guinea pigs produced no effect. A 24 hour mixture was uncertain in its effect, some animals recovering after two cubic centimeters by intraperitoneal injection; one died promptly

of sepsis. All those recovering had an elevated temperature and lost rapidly in weight for several days.

4409 (Gives list of pathogenic and non-pathogenic bacteria found at Joliet.) Injection of four cubic centimeters into guinea pigs produced no effect. Of four guinea pigs inoculated with one cubic centimeter of 24 hour culture, one died of sepsis and the others recovered.

4410 Examined two specimens from the Kankakee river at Wilmington. Found no pathogenic bacteria. (Gives names of non-pathogenic bacteria found.) Injection of water and bouillon culture proved non-pathogenic. (Objected to by Mr. Jeffries for the reason that there is no evidence showing that such samples were ever taken, and that they were properly taken, or by whom taken.) (Gives names of pathogenic and non-pathogenic bacteria found in the Illinois river at Morris.)

4411 Injection of one specimen of this water caused death of guinea pig in 11 days. No post-mortem findings or bacteria were found in the blood or organs of his animal. Other samples of water from the same place did not cause death by direct injection. Experiments with mixed cultures gave uncertain results. The animal sometimes dying and other times not. (Gives names of pathogenic and non-pathogenic bacteria found in the Illinois river at Ottawa.) Both the water and the mixed cultures proved non-virulent after intraperitoneal injections into guinea pigs in the same manner. In samples of water from the Fox river at Ottawa, found bacilli coli communis and non-pathogenic bacteria named.

4412 Neither the water nor mixed cultures proved pathogenic to animals. (Gives names of pathogenic and non-pathogenic bacteria found in Illinois river at La Salle.)

4413 One guinea pig receiving injection of four cubic centimeters of this water died of sepsis, the others recovered, but the bouillon mixture proved very virulent to guinea pigs. (Gives names of pathogenic and non-pathogenic bacteria found in Illinois river at Henry.) Direct injection of water did not cause death. Mixed bouillon cultures were virulent.

Found bacilli coli communis and non-pathogenic bacteria named at Averyville or Upper Peoria.

4414 Direct injection of water as well as mixed bouillon cultures proved entirly non-virulent, even large doses of 24 hour cultures could be given without causing death.

4415 I have taught classes in bacteriology for years how to find pathogenic bacteria in various mixtures and waters.

My problem in this investigation was to determine the presence or the absence of pathogenic, that is, disease-producing bacteria in the specimens of water presented to me. As to experience, I have that of a teacher in bacteriology. I have taught bacteriology for five years, and while I have not an extended experience in sanitary investigations, I certainly have done enough work in the separation and identification of pathogenic bacteria, I think, to feel that I am entitled to an opinion as to whether they disappear or not, and that is what I have done in this case.

MR. JEFFRIES: I object for the reason that the tables in evidence are incompetent, that there was not a sufficient number of samples examined; the character and changes of water with reference to flood times and winter seasons were not so followed as to enable any scientist to express an opinion; that the witness has not shown that he is acquainted with bacterial organisms and changes of river waters and has not had sufficient experince with reference to the bacterial examination of running streams.

A. I think I have distinctly stated in the beginning that my part of this investigation was the finding and identification of pathogenic organisms, and such other sewage and water bacteria as could be identified, and I have, I think, qualified sufficiently in that direction. I found that there was a gradual decrease in the number as well as in the kind of pathogenic or disease producing bacteria in the water specimens submitted as we got further away from Chicago. Further, I found that bacteria that are generally known as sewage bacteria or saprophytic organisms gradually decrease as we aproach Upper Peoria. The number as well as the kind of disease-producing bacteria, as well as the sewage bacteria, is continually decreas-

ing to this point, and the absence of pathogenic effect in animals, I think is also a sufficient proof that the zone of bacterial self-purification, which every river has, which has become polluted, must be located somewhere above or near Upper Peoria.

4417 (Gives names of pathogenic and non-pathogenic bacteria found in Illinois river at Lower Peoria.)

4418 Direct injections of the sample caused death of a guinea pig in eleven days. Another animal died of sepsis within 24 hours after inoculation. The pathogenic and saprophytic bacteria have again markedly increased. (Gives names of pathogenic nad non-pathogenic bacteria found in the Illinois river at Havana.)

4419 Several of the specimens of this water proved highly pathogenic to guinea pigs and white mice, when intraperitoneal injections were given, and numerous animal experiments were necessary to prove beyond any doubt that anthrax spores must have been in two samples of this water. We injected finally pure cultures of all lanthrax-like organisms obtained from these water specimens. A number of the animals died within 40 to 48 hours of anthrax bacteremia, the blood of all the organs containing enormous numbers of anthrax bacilli. The colon bacillus and the staphylococcus areus found a few times in these samples proved non-virulent, when pure cultures were injected into animals, whereas the proteus forms were very virulent.

(Gives names of pathogenic and non-pathogenic bacteria found in Spoon river, near Havana.) Injection of four cubic centimeters of the water into guinea pigs in two cases did not prove fatal. Bouillon cultures were non-virulent in doses of one cubic centimeter by intraperitoneal injection.

4420 (Gives names of pathogenic and non-pathogenic bacteria found in the Illinois river at Pearl.) Neither water nor culture was pathogenic by intraperitoneal injection. (Gives names of pathogenic and non-pathogenic bacteria found in Illinois river at Grafton.)

4421 Neither waters nor mixed cultures proved fatal. Ordinary water bacteria multiply in river water and pathogenic bac-

teria do not. The conditions of the water bacteria are the same everywhere, that is, they will be able to grow and multiply even when there is very little organic matter present and even at low temperature. The condition of growth of the saprophytic bacteria depends more or less on the presence or absence of dead organic material; the more organic material, the greater the number of saprophytic bacteria, and they usually require a somewhat higher temperature for rapid multiplication than do the water bacteria. In other words, the greatest multiplication of saprophytes will take place in the presence of the greatest quantity of organic material, and a temperature slightly above that of the lake or river water. The existence or disappearance of disease producing bacteria, typhoid bacilli, the cholera vibrio, and various pus micro-organisms depends upon dilution, light, the tempetature and the presence or absence of large numbers of saprophytes. Conditions exactly as shown by experiments are these: In the presence of many saprophytic bacteria, that is, at a temperature at which saprophytes grow best, at room temperature, typhoid bacilli, staphylococci, anthrax bacilli, and similar pathogenic bacteria are rapidly overgrown by the saprophytes and disappear from the mixture. Even in the absence of organic material where there are only water bacteria present, the water bacteria multiply also at a tremendous rate, and we find that the typhoid bacilli disappear in eight or ten days. In the first case, where many saprophytes are present, there is a great multiplication of saprophytes at room temperature, and the typhoid bacilli are overgrown and disappear very much sooner, in five or six days. When there are only water bacteria and no colon bacilli, no sewage contamination, but simply the common water bacteria, as found at times in pure Lake Michigan water, or non-polluted river water, the typhoid bacillus lives somewhat longer. If typhoid bacilli are put into a sterile water they can live still longer than in either one of the other cases. The typhoid bacillus in sterile water can live for weeks, even in the absence of food. These statements are all based on personal experiments and I have repeatedly

observed that in the presence of such organic material the greater the number of saprophytic bacteria, the sooner the cholera vibrio, staphylococci, anthrax and streptococci and typhoid bacilli will disappear. Another point which I ought to add here is, the higher the temperature of course, the more favorable it is for the growth of the disease producing bacteria, and that in the low temperature of a river or lake water the typhoid bacillus can not multiply. These lower temperatures are favorable to the growth and multiplication of water bacteria and many saprophytic bacteria. The typhoid bacillus in the absence of many water bacteria and saprophytes might live for some time. The smaller the number of saprophytic bacteria which are present, the longer, of course, the typhoid bacilli may exist, and the less they will be overgrown by the rapidly multiplying saprophytes or sewage bacteria or water bacteria. Every lake and every river has a normal bacteriological flora. By water bacteria, I mean bacteria which do not cause putrefaction, which do not produce gas, which do not produce indol, which can live even where there is little or no organic material present.

4423 They are organisms that are found in every water. By saprophytic bacteria or sewage bacteria, I mean those which produce gas, cause putrefaction, coagulate milk, produce acids and so on, and require for their rapid multiplication organic material in a larger quantity, and a higher temperature than the water bacteria. The water bacteria grow and multiply best at the temperature of the water; the sewage bacteria or saprophytic bacteria grow best at room temperature. The pathogenic bacteria are disease-producing bacteria and grow best at blood temperature, so that when the three are mixed, it is mainly a question of temperature as to which kind will multiply most. If you mix pathogenic germs and saprophytic bacteria and keep the mixture at blood temperature, the pathogenic germs will multiply more rapidly than the saprophytes; but if you keep them at the tempertaure of air, the saprophytic bacteria, in the presence of much organic material, will increase at a tremendous rate, whereas the disease producing organisms cannot multiply

because the temperature will not allow them, and they are overgrown by the saprophytes. For instance, the typhoid bacilli doesn't multiply at all at the temperature of water. The typhoid bacillus grows best at blood temperature, 37 degrees, but can grow at as low a temperature as 24 degrees Centigrade. There must be organic material for food. With other rapidly growing bacteria at this temperature, the typhoid bacillus will be overgrown and will disappear, even when the temperature is in the neighborhood of 24 degrees to 30 degrees due to the rapid growth of the ohter bacteria present.

4424 Some five years ago Prof. Klebs suggested that I test the question of the longevity of typhoid and other pathogenic germs. At that time, we made a number of experiments with common tap water. We found that the typhoid bacilli in all flasks, in all temperatures, disappeared at different times. If we kept the flask at room temperature, we found that the water cocci increased at a tremendous rate even in a few days, and that the typhoid bacilli we had inoculated it with in all cases and in all flasks had died after three weeks.

4425 At blood temperature in diffuse daylight and another set in the dark room, we obtained colonies for a little over two weeks. At room temperature in the dark, we obtained colonies for ten days, but at room temperature in the light, we obtained colonies for about eight days. We found that the typhoid bacilli disappeared very soon when sewage was added, in fact much sooner; after five or six days we were unable to find typhoid bacilli in any water to which we had been adding sewage. We became thoroughly convinced from our work at the time that typhoid bacilli in the presence of much organic material and the overgrowth of saprophytic bacteria disappeared entirely from the water inside of a week; that if only water bacteria were present and no sewage contamination, typhoid bacilli could live a somewhat longer time, but that no multiplication took place at the temperature of lake and river water and they fin-

4426 ally were annihilated. Whenever saprophytes were numerous, the typhoid bacillus disappeared rapidly, that

is, in five or six days. Briefly stated, in the presence of water bacteria only, the typhoid bacillus can live a longer time than in the presence of such organic material and saprophytes, but in all cases it rapidly disappears from any water to which sewage is added. In determining the purity or impurity of a stream or body of water, the number of bacteria has not as much importance as the kind of bacteria. The number may be great and not have much significance, whereas if they are sewage bacteria and pathogenic bacteria, the number may be very small and the water might be called perfect chemically and yet it might not be called perfect bacteriologically. If the water contains only 50 germs and those happen to be disease producing germs, that water should be condemned. The number is only significant in so far as after the normal number of bacteria in a stream, lake or river has been once determined in the summer and winter, at all times and in all conditions, a sudden great increase in the number found above that which is normally found under like conditions would mean pollution. In the numerous bacterial examinations which I have made of the water of the Drainage canal and the Illinois river, I have not found the typhoid bacillus. Nor is that strange. We cannot find the typhoid bacillus usually because even if sewage, contaminated with typhoid bacilli, should get into the lake for instance, the dilution would be so tremendous that it would be very difficult to find them again. The typhoid bacillus does not multiply at the low temperature of such water, and in case of sewage contamination of lake and river water, the sewage and water bacteria overgrow it and other elements such as tremendous dilution, and the effect of light, cause its disappearance. Even where we know that pollution of a water supply with sewage containing typhoid bacilli has taken place, bacteriologists cannot find typhoid bacilli. First the unfavorable temperature of water prevents multiplication of pathogenic germs. Secondly, sewage bacteria or saprophytes undergo rapid multiplication and overgrow the parasitic bacteria. Third, extensive dilution takes place and separates the bacilli so far that the bacteriologist is unable to find them

any more. Another factor to be considered is that in most of the epidemics where bacteriologists have searched for typhoid bacilli and were unable to find them, the time of infection or of contamination has no doubt been passed by several weeks, and typhoid bacilli, which might have been found earlier, have been entirely annihilated during the period.

4428 I think with our present means of differentiating the typhoid bacillus, if the typhoid bacillus was present in the water, we would in examining one cubic centimeter be able to determine that fact.

4429 If there was only one germ of any pathogenic kind, in four cubic centimeters of water, when intraperitoneally injected, it would not produce any effect. Even much greater quantities than that might not produce any virulent effect. A few germs do not produce an infection, even if they are virulent or pathogenic germs. That is true in all cases. The number is just as essential as the presence of the germ itself.

4430 It is true that in all infectious diseases the number of the germs is very essential in producing an infection. We find that of persons who die of other diseases, 90 per cent have evidences of an infection by tubercle bacilli somewhere in their bodies. I mean healed tubercular foci. The same also holds true of typhoid. The number of typhoid bacilli essential to produce infection are not found in the amount of water usually used by an individual for drinking purposes, be it lake or river water. I do not believe personally that direct infection can take place in such a manner. I think that if all the sewage of Chicago containing the typhoid bacilli from every case of typhoid fever in the city should get into Lake Michigan, that no one could be infected by the water of Lake Michigan directly, because the dilution of the bacilli and of such sewage, would be so great that one would have to swallow thousands of quarts of water to supply the necessary numbers of typhoid bacilli to produce typhoid fever, and that yphoid infections, in view of the fact that typhoid bacilli do not multiply at the low temperature of water, must take place in an indirect manner. To illustrate, the infected water containing we will say, one typhoid bacillus to so many thousands of gallons, would reach some favorable culture medium, like various food

products, and in a favorable temperature, like that of a hot summer day, or in the house, in milk, or in oysters or in vegetables, or in various other foods, the few typhoid bacilli present begin to multiply and produce a pure culture in, on or upon these foods, a person taking of such food, will swallow the necessary number of typhoid bacilli, to bring about an infection, and have typhoid fever, because he has swallowed
4431 a culture of many millions of typhoid bacilli, whereas, the other idea of the direct infection by drinking the water is illogical, when we consider the biology of the typhoid bacillus, and the tremendous dilution that takes place when turning sewage or other pollution into a large body of water, and the fact that the typhoid bacillus does not multiply at the low temperature of lake or river waters. If the sewage gradually disappeared and with it the sewage bacteria, I would judge that by the overgrowth of saprophytes in the presence of organic material and a temperature favorable to rapid multiplication of saprophytes, pathogenic bacteria that might have been present in this mixture, have been wiped out entirely. In other words, by the rapid multiplication of sewage bacteria, the disease-producing bacteria which grow best at the temperature of the body will be overgrown and perish, so that by the time the sewage bacteria and organic material has disappeared, the purification of the river or lake, of pathogenic bacteria, must be most complete.

4432 I have gone all over the territory of the waters of the Chicago Drainage canal and the Illinois river from Chicago to St. Louis and have seen the water and formed some opinions in regard to it. I have recently, about two weeks ago, something like that, gone over this whole region and observed the conditions that prevail in these streams.

4433 I think that in the Drainage canal the growth and multiplication of immense numbers of saprophytes, due to the presence of a large quantity of organic material, is unfavorable to the life, the multiplication, or even the existence of disease-producing bacteria. I believe that in the Drainage canal the conditions must be such that they are gradually wiped out, whereas, in the Illinois river, the saprophytes are less numerous, and any disease-producing bacteria that would

enter the Illinois river, would be tremendously diluted, but they could probably exist no longer in the Illinois river than they could in the Drainage canal. Any disease-producing bacteria that would get into the Illinois river could, on account of the absence of the decrease in the number of saprophytic bacteria, live no longer. The question could be answered by saying that in the Drainage canal the existence or multiplication of pathogenic, disease-producing bacteria would be made impossible, and that they would disappear in such a sewage tank would depend also upon the resistance of the organism, but during the overgrowth of saprophytes. The time, of course, under the conditions of my laboratory experiments, I would judge that a week ought to be sufficient to wipe out all the cholera vibrio, staphlococci and typhoid bacillus.

4434 The tables found beginning on page 21 and ending on page 23 of pamphlet entitled "Illinois State Board of Health Advance Sheets of Report of Sanitary Investigation of the Illinois, Mississipi and Missouri rivers, 1902," were prepared by me from samples of water furnished to me by Professor Long, at the time stated in those tables.

4435 They were made between October 3, 1901, and March 11, 1902,at my laboratory, Northwestern University Medical school.

4436 We used all the water in these samples and made cultures from it, and afterwards injected guinea pigs with one cubic centimeter of this water after the mixture, it having remained 24 hours in the incubator. We examined 38 specimens of water from the Illinois river at Grafton and 37 samples from the Mississippi river some distance up, before the Illinois river joined it.

4437 MR. JEFFRIES: We move to strike out what witness says with reference to point samples are supposed to have been taken from in the Mississippi river and because there is no evidence showing these particular samples which he examined were the identical samples which were collected from these various rivers and sent to Professor Long and for the reason that the samples that he examined had not been properly identified in evidence.

4438 I took down the numbers which I found on those bottles and which you will find in this report as to bacteriological findings. The dates and the numbers were always given to me by Prof. Long with the bottles. I received 36 water specimens from the Missouri river, which were marked with the date and number given in this report.

At the time I made the examination, the samples were numbered and it was frequently the case that we did not know whether it was Illinois, Mississippi or Missouri water. When we were through with our investigations we had to assort all these numbers according to Prof. Long's record to tabulate them under these headings: Illinois river, Mississippi river, Missouri river. The tables found on pages 21, 22 and 23 of the pamphlet, called advance sheets, are those prepared by me at that time.

4440 prepared these tables from the originals in my office that I made myself. I have the original tables from which these were printed, in my possession.

4442 Table No. 1 of the investigation of 1901-2 shows the bacteria and other micro-organisms found in 38 water specimens from the Illinois river.

4443 (Objection by Mr. Jeffries, because witness has not properly shown the particular place where these samples were taken.)

4444 The table which has just been put in evidence is the result of examination of water taken from the Illinois river at its mouth or at Grafton above its mouth.

4445 The cross in the table means that the particular organism was found in the specimen of water whose number ppears in the second column. The date given here represents he date we received the specimen. Where there is a blank he organism was not found in that specimen of water. The ivision marked "Other Micro-organisms" were organisms hich were but rarely found and which received no special column therefore.

4446 Table No. 2 shows results of examinations of 37 specimens of Mississippi river water from Oct. 8, 1901, to larch 11, 1902. This represents the examination made in the Mississippi above the mouth of the Illinois.

4447 Table No. 3 shows result of examination of water specimens from the Missouri river.

4448 In my testimony today in reference to the examination of waters of the Illinois river, I stated that the self-purification of the Illinois river began at Morris and was practically completed between Henry and Upper Peoria.

4449 After a consideration of the results of the examinations to which I have just testified, I do not see any reason for changing the opinion expressed, that bacterial purification has taken place in the Illinois river long before the water reaches Grafton. For the purpose of the identification of pathogenic bacteria and for determining the virulence of such bacteria.

4450 I have plated out the suspected water and obtained pure colonies of the various organisms found, passed them through the usual cultures in order to identify them, and immediately after platin gout, I have added to the suspected water enough nutritive bouillon to the four ounce bottle of the specimen of the water to favor the growth of the bacteria therein, and incubated the whole bottle for 24 hours at 37 degrees centgrade. After the time I injected one cubic centimeter of the water, enriched in pathogenic or disease-producing bacteria intraperitoneally, into guinea pigs. When the animal died, a complete bacteriological examination was held and the cause of death determined. Cultures were made from all the organs of the animal, particularly the blood, the spleen and the lymph glands and the contents of the abdominal cavity. We also made a number of side experiments in order to arrive at a more certain diagnosis of the pathogenic bacteria found there. We also tried more modern means of precipitating typhoid bacilli by agglutination, if there should be

4451 any, and then enriching the water, using the serum of an immunized rabbit to agglutinate the typhoid bacilli, but these efforts to detect typhoid bacilli proved entirely unsuccessful and we dropped that again. In fact we never produced any precipitation, so we gave it up. If there had been one typhoid bacillus in one of these bottles, there would have been millions of typhoid bacilli in 24 hours in this water in the

incubator. In fact we have done that. We have taken other water specimens not from these sources and we have added minute quantities of typhoid bacilli to the water in the regular laboratory cases and after incubating them for 24 hours had them plated out and the colonies and cultures that looked like typhoid colonies we ran through and tested as to whether they were typhod bacilli. So, according to this method, it seemed to me we were able to find typhoid bacilli even if there was one cubic centimeter of bouillon culture to a million liters of water.

4452 If there had been one bacillus of typhoid fever in any one of these bottles, I would by this process have increased the number to such an extent that they could easily be found. I inoculated the water with a known quantity—a very small quantity and yet was able to find them afterwards by this enriching process. I am of the opinion, that by this enriching process I should have succeeded in finding colonies of typhoid bacilli if one bacillus had been present in the water, although I, of course, repeat again that difficulties may arise in some specimens containing great numbers of colon bacilli. I did not in any of these investigations find the presence of the bacillus typhosus. I found a number of other pathogenic bacteria. (Witness gives names of pathogenic bacteria and the number of times they were found in the Illinois, Mississippi and Missouri rivers.)

4454 During the spring of 1902 we found great numbers of moulds, numerous spores of moulds, such as mucor, aspergillus and odium types in great numbers. I think they were mainly found in such great numbers on account of the entrance of surface waters into the river during the early spring.

4455 The specimens we received were ice-packed. There could have been no multiplication of the pathogenic bacteria present. The typhoid bacillus can grow at 75 Fahrenheit. It grows best at 98 2-5 Fahrenheit. It will not multiply below 20 centigrade or 68 Fahrenheit. It will not die by freezing and it will die at a temperature of 60 in ten minutes, 60 centigrade being equal to 140 Fahrenheit.

4456 Under the conditions in which I received these samples of water there would not have been any increase of typhoid bacilli between the time of the packing of the sample and the making of the examination, if there had been any present in the water. Assuming that the dejecta of typhoid fever patients in Chicago were deposited in the sewers of the city and carried into the drainage canal and that the canal contained immense numbers of saprophytes and ordinary water bacteria to the number of 70,000 and frequently as many as 4,000,900 per cubic centimeter and assuming that it required at least 24 hours and as much as 48 hours for the water to pass from Chicago sewers into the Chicago river and canal and Bear Trap Dam, and assuming that the flow in the Des Plaines and Illinois river is equal to 40 miles in 24 hours, in my opinion such

4458 typhoid bacilli would not survive for the reason that the saprophytic bacteria increase at such a tremendous rate in the drainage canal as to actually overgrow and annihilate any pathogenic or disease producing bacteria. Knowing the conditions that exist in the waters of the Chicago river, the drainage canal, the Illinois, Mississippi and Missouri rivers at their confluence, and taking into consideration the enormous dilution which the sewage passing through the drainage canal receives from Lake Michigan and from other sources on its way to the Chain of Rocks, in my opinion it is not possible for typhoid bacilli deposited in a sewer in Chicago which empties into the Chicago river to reach the intake of the St. Louis waterworks. My opinion is based on the fact that whenever conditions are favorable for the rapid multiplication of saprophytic bacteria, pathogenic bacteria disappear. It is my opinion further that the reason why reputable bacteriologists have been unable to find the typhoid bacillus in the polluted supply of streams or localities where a typhoid epidemic existed, was due to the same cause. (Objection by Mr. Jeffries.)

4459 In regard to the bacteriological flora of the three rivers during the examination of 1901-2 from the investigations made as a bacteriologist I would judge that the Missouri was

more polluted than either the Mississippi or the Illinois during the periods of these examinations and that the Mississippi was more polluted than the Illinois at the same time. (Motion to strike out by Mr. Jeffries.) This investigation is entirely independent of any other data.

4460 It is simply to determine if the water of these three rivers specimens of which were examined, is to be condemned bacteriologically, and which of the three is more dangerous than the other two, and I think bacteriologically and qualitatively that can be determined a great deal better in this way than by a great many of the methods that are employed sometimes as the more dependable methods by sanitarians. A physically pure water that contains a great number of pathogenic bacteria is certainly to be condemned. A water may be physically bad and contain a thousand times the number of bacteria that the other water contained and yet it may not contain any pathogenic bacteria. In spite of its apparent bad character physically it need not be condemned. I would be perfectly willing to swallow water, in which I was capable of producing a culture, like I have done here and keep it 24 hours in the incubator and inject it intraperitoneally into the abdominal cavity of a guinea pig, without any effect. After all, the question of determining the safety of drinking water from a river or a lake does not depend upon its physical character and the number of bacteria that may be present, but depends upon the number and kind of pathogenic bacteria present in the water. I testified as a medical bacteriologist, and I believe my opinion in this matter has some cause and some Justice. In my examination yesterday I gave bacterial results of certain examinations of lake water taken from the tap at my laboratory, for the purpose of ascertaining if possible the longevity of the typhoid bacillus.

4461 If there is to be any comparison as to which of these experiments conformed most nearly, if at all, with the condition of the waters of the drainage canal, the only comparison that could be made would be to say that the one nearest to conforming to conditions in the canal is, of course, the one with the

lowest temperature. The conditions for the disappearance of typhoid bacilli from the waters here were if anything more unfavorable than they would be in a water like the drainage canal which is teeming with saprophytic bacteria. If I had used water from the drainage canal instead of Lake Michigan, I should judge that they would disappear sooner yet. In Lake Michigan water, the shortest time in which these bacteria lived was six days. If drainage canal water had been used the time would have been at least as short.

4462 I believe modern sanitation owes its advance mainly to the advance of bacteriology. Modern pathology and sanitary science have been entirely changed as we have learned to know the etiology of infectious diseases and their spread, so the modern sanitarian makes a specialty of applying what we have learned from chemistry, bacteriology and associated branches in the study of infectious diseases, as well as their prevention.

(Witness states what advantages modern investigations by bacteriologists have afforded sanitation.)

4463 I graduated at a medical college in 1887. Since that time we have learned to know the causes of many infectious diseases and we have learned how to cure and prevent such diseases by the employment of substances which either destroy the germ itself or will destroy its poisonous products, as for instance diptheria anti-toxins and tetanus anti-toxins, etc. We think the longevity of the bacillus prodigiosus and the typhus bacillus is quite similar.

4464 Assuming that they were in the waters of the Illinois river and the Illinois and Michigan canal, the longevity of the prodigiosus should be longer than that of the typhoid bacillus because the optimum temperature for the prodigiosus is 25 degrees centigrade or 77, Fahrenheit. The optimum temperature of the typhoid bacillus is 98 Fahrenheit. (Witness states method of ascertaining presence of prodigiosus in water.)

4465 If while making an examination for the presence of the

prodigiosus I should reach that point in the investigation where the red color appeared, and were to stop there, we could not be certain by the color alone whether we had prodigiosus or some other red organism. I have never, in my bacteriological examinations of the waters of Lake Michigan, Chicago river, Illinois river or the drainage canal, discovered the presence of the bacillus prodigiosus. In Lake Michigan I discovered the presence of a bacillus which disclosed the red color to which I have referred. In 1900 in the early part of our work we occasionally obtained a few red colonies which appeared to have all the characteristics of the prodigiosus. This organism was different, however, from the prodigiosus in the fact that it grew very well on sterilized banana slices and the organism itself was larger than the prodigiosus commonly is, and it occasionally produced some gas. If I had rested my experiments on discovering the red appearance to which I refer, I would have called it a prodigiosus. In fact, I did at first.

4466 I stated yesterday that the zone of bacterial purification of the waters of the Illinois as disclosed by my examinations of that river had been reached at Averyville, just above Peoria. The zone of bacterial purification is that part of a sewage polluted river, where saprophytic organisms and pathogenic bacteria have disappeared and where the normal bacteriological flora of the river, before it received such pollution, is again established. In other words, where practically the same bacteria are found or exist that are found in the same river before it receives such pollution. The zone of bacterial purification varies in the different localities and in the different cities that empty their sewage into rivers, in its distance between very short distances, as short as nine miles, and longer distances, to the extent usually of forty miles. As an example of other rivers where the zone of purification has been ascertained by bacteriologists, I might refer to the Seine, in Paris—a distance of 43 miles. The river Oder at Breslau, at 33 kilo-

meters below the city. At Zurich, Switzerland, we have the lake sending out a river, the Limmat. The lake water contains only a few bacteria, and is considered very pure. The river receives all the sewage and the effluent of Zurich and has again 14 kilometers below the city, practically the same bacteriological flora that it had before receiving the sewage.

4467 33 kilometers is the purifications zone of the Isar in Munich. 33 kilometers is about 20 miles. 100 kilometers is about 62 miles. The Isar at Munich purifies itself in a distance of 20 miles.

4468 These data were compiled in 1900 and 1901. They are in the German language and appear in the Zeitschrift fur Hygiene, page 56, volume 190, in which is contained the investigation made by Schlatter, of the Limmat, in Zurich. The river Seine you will find in Rubner—Hygiene, Berlin. The Oder is given in Frankland and the Isar is given in Prausnitz—Hygiene. The Spree, in Berlin, also receives sewage which then allows the bacteria to raise up to 1,000,000 per cubic millimeter. Then it goes into the small lake of Havel and at the exit of the lake, or Sacrow, the bacteriological flora is again the same as it was in the river Spree before it entered the city of Berlin. This is also given in the Zeitschrift fur Hygiene, page 355, volume 3. I should ujdge the whole distance travelled in that lake is about nine miles.

4469 As to the Illinois river, I think the zone of purification here ought to be even nearer to the city of Chicago than what I have allowed, in fact I think that the zone of purification is above Upper Peoria. I spoke of it simply there as being bacteriologically complete. I believe that the real zone of bacterial purification is complete very soon after leaving the drainage canal.

4470 DIRECT EXAMINATION, By Mr. Todd.

The samples of water which I examined or analyzed in both of these investigations I received directly from Prof. Long. They were numbered. My analyses were based on these samples and my tables correctly indicate what the numbers signify. They

did not always state as to the places from whence they were taken. When the place was not on the sample, I sent to Prof. Long, and with the number, secured from him the location. In my opinion, those examples which I have related in my answer to the question put by Judge Springer, as to the zone of purification of running streams are examples recognized by the scientists of Europe as established scientific facts. My opinion is that typhoid bacilli lying in the bed of streams for a period in excess of sixty days would be dead after remaining in such sediment for that length of time.

4472 My opinion would be that pathogenic bacteria from the Chicago river would have died in the drainage canal before reaching the Illinois river, due to the great increase of saprophytic bacteria and the overgrowing of the pathogenic germs both in the sewers and the drainage canal. As to pathogenic bacteria it is my opinion there will be no source of danger to St. Louis or the inhabitants of Missouri from sewage deposited by the drainage canal from Chicago into the Illinois river at different seasons of the year and at different stages of water in the Illinois river, that is, if they use this water for drinking purposes. From 38 specimens of the Illinois river and 37 from the Mississippi river and 36 from the Missouri river made during the months of October, November and December, 1901, and February and March, 1902, I concluded that bacteriologically the Illinois river was less polluted than either the Mississippi or Missouri. During the period of these examinations, the effect of emptying the Illinois river into waters in which the Missouri river was a part would have only tended to make the Missouri less infectious, because the Illinois river was less infected than either the Mississippi or the Missouri was during those times. I would say that there would have been no source of danger to add the Illinois to the already severely polluted Mississippi or Missouri.

4474 I do not believe that the drainage canal or the sewage entering the drainage canal can be of any danger due to pathogenic bacteria remaining in it, to St. Louis or Missouri,

for the reasons already stated. My opinion being based mainly on the behavior of pathogenic bacteria in the presence of saprophytes and my opinion also being based on the general
4475 knowledge the world over of the existence of a bacterial zone of purification in any river, and a continuous and permanent purification as the river flows along. As it flows along new pollution occurs and new bacterial purification zones form, which is my reason for feeling certain that no pathogenic bacteria entering the sewers of Chicago, or the drainage canal, will pass beyond Averyville, where bacterial purification was complete. This distance is much greater than that which is generally found the world over, in every river. I would have liked of course very much to have more material, make more examinations and to determine more positively the exact place of the bacterial purification, which I am quite certain is far above Peoria. I wanted to feel safe in saying that the absolute disposal of all pathogenic bacteria had been completed for the reason that even the saprophytic bacteria and the sewage bacteria have disappeared, and for the reason that here, practically no bacterial pollution whatever of the river existed. Practically the same condition would apply to the germs of Asiatic cholera that apply in the case of typhoid bacillus. As to the question whether the germ of typhoid fever could lie in the sediment of the drainage canal or the Illinois or Mississippi river for a period of one to five years and still retain its virulence, I will say that I am thoroughly convinced that typhoid bacilli even under the most favorable conditions would not live one year, much less five years. (Witness is asked hypothetical question involving the dumping of 107 barrels of prodigiosus at Lamonte, the taking of samples night and day for the purpose of discovering that bacteria as it went down the river, and the finding of one bacillus at the Chain of Rocks, and two at Grafton, and was then asked his opinion as to the value of these experiments.)

A. In the first place, there would be considerable doubt whether the red colonies were really prodigiosus colonies. In

the second place, the great numbers that were poured into the canal and the practical absence of them afterwards would only indicate what the self-purification of rivers means, because this germ grows best in room temperature. It would perhaps not die as easily in water as the typhoid bacillus because it would probably exist better than the typhoid bacillus under those conditions. I think it would prove that if it is true that the prodigiosus disappears under such conditions that it would be much more true of the typhoid bacillus.

4479 In order to establish the identity of the germs denominated bacillus prodigiosus that were found at the places indicated in the last hypothetical question, it would be necessary to pass the germs through different culture media, and it would be necessary that this germ conform to the description as given in the literature in order to name it a bacillus prodigiosus. It cannot be distinguished by the color alone.

CROSS-EXAMINATION, By Mr. Jeffries.

4482 I have inoculated liter flasks with known quantities of the typhoid bacillus in lake water, into the Missouri river water, into the Mississippi river water, into the Illinois river water. Some of these experiments were made at a temperature of 12 degrees centigrade. Those of the Illinois river water at Grafton and the Mississippi and Missouri river water were made at a temperature varying from 10 to 12 degrees centigrade in the refrigerator. I did not describe those experiments yesterday because I was not asked to do so. At that temperature I was not able to find a typhoid bacillus in five days and in six days.

4483 (States how experiments were made.) The water in which these experiments mere made came from the Illinois river at Grafton, the Missouri above its mouth, and the Mississippi before the Illinois enters it.

4485 Out of 38 samples of Illinois river water from which boullion mixtures were made after 24 hours incubation we tested six samples on animals with the result that the ani-

mals usually died of proteus infection, but not always. As to the typhoid experiments, the temperature was 50 to 53 degrees Fahrenheit. The cause of the earlier death here is the overgrowth of saprophytic bacteria that grow best at a low temperature.

4486 These experiments in the investigation of the life of typhoid bacillus in river water involved about ten tests and were made in a refrigerator. Sometimes after four days we were unable to find any colonies of typhoid bacilli. If the samples can be prevented from changing by ice, I think it is true that when river water is at the temperature of ice as it is at the coldest part of the year, that it would be correspondingly protected from changes in composition.

4487 The amount of organic matter coming from the bouillon containing the culture of bacteria was very little. No analyses were made to determine the amount of organic matter contained in the water in which my experiments on the life of typhoid germs was made and the aggregate amount of organic matter coming from the bouillon contained in the culture of the bacteria. In making these experiments I first make a bouillon culture of typhoid bacilli. That is grown for

4490 24 hours in the incubator and then I take one loopful and add it to five cubic centimeters of river water. After that has been added this is immediately plated out on agar. In the following experiments we do not plate out until the typhoid bacilli have been in the water for one day, two days, three days, four days and so on, until we do not find any more typhoid bacilli in the plates. This loopful of bouillon culture contains an inappreciable amount of organic matter which produces this saprophytic growth. This saprophytic growth brings about the death and destruction of typhoid bacilli, but the organic material which I have added by one platinum loopful of bouillon culture is inappreciable compared to the amount of organic material which must already be present in that water.

4491 I do not see what difference there exists whether I add typhoid bouillon to the river water or whether the typhoid bacillus enters that water in the form of fresh sewage conatining typhoid bacilli. I believe in fact that in my case I am introducing less organic material with the typhoid bacillus than under natural conditions where sewage containing typhoid bacilli enters the water. My experiments only show the longevity of the typhoid bacillus in that water under condi-
4492 tions as they exist in the laboratory. Those conditions are different from what they are in the river, although I have made them as closely similar to those of the river as I could. I believe that the conditions in a seriously sewage polluted water, are more unfavorable for the life of the typhoid bacillus than they would be in the laboratory experiments, on account of the greater amount of organic material that would be present there. My experiments were all done with water that was not seriously polluted. I mean that the water specimens I experimented with did not contain abnormal amounts of saprophytes, like, for instance, the water in the drain-
4494 age canal. In my direct examination I spoke of the purification of the sewage from European cities, Munich, Zurich, Paris, Berlin and Breslau. The effluent of the sewage from those cities passes into the rivers mentioned and is absorbed by the waters of these rivers and reduced to harmless substances within the distances which I have mentioned, and without injury to those residing on the rivers below the points of the purification zones I have mentioned.

4495 I speak of the general proposition that any river ought to be polluted as little as possible where it is necessary that towns near by use that water for drinking purposes. That is not from a bacteriological standpoint but from a general hygienic standpoint supported by the science of bacteriology and by the science of hygiene. Bacteriology has something to do with the science of hygiene in so far as hygiene originally taught us that there was no river long enough that it could purify itself of any pollution that it received, and as bacteri-

ology has proven that that dogma is not correct and that there is in every river a purification zone.

4496 English authorities on hygiene taught twenty years ago that no river was long enough that it could purify itself of any pollution that it received. As soon as bacteriology was employed an entirely different condition was found. It was found that there is a zone of bacterial purification in every river and that sewage bacteria turned into it really disappeared within a certain distance. I, as a bacteriologist, have of course accepted that view and based upon my own findings in the matter have expressed it also as my opinion that there is a bacterial purification zone in every river.

4498 It has been known particularly that there is a zone of purification from a bacteriological standpoint in every river since these questions were investigated at Zurich, Berlin, Munich and Breslau. I am not able to state whether that was prior to the construction of these sewage purification plants at these various places.

4499 I do not know that since these sewage purification plants were established in Europe, various cities throughout Europe and the United States are today expending large sums of money to purify their sewage and remove from it the objectionable material before it goes into the rivers.

4503 There is no question in a general way, that the discharge of the sewage such as ordinarily is discharged from sewers of large and populous cities of this country, without treatment of some kind, into a river renders the water in that river in a less sanitary condition than without the sewage. I do not know whether or not the city of Peoria abandoned the Illinois river as its water supply some years ago. I do not know the condition of the Illinois river prior to the opening of the canal, as far as Peoria.

4504 Bacteriologically considered I would not think it necessary for Peoria to abandon the Illinois river as a water supply. I do not speak as a sanitarian. A water may be chemically and physically pure and yet contain pathogenic bacteria

and bacteriologists would condemn that, whereas the chemist and sanitarian does not make those examinations and would consider that a pretty fair supply. If I found pathogenic bacteria anywhere I would consider that substance whether it be food or water, as dangerous and to be prohibited from using it. It is not a question of the number of bacteria of all kinds and classes that are found in a water that condemns it. It is the presence of pathogenic bacteria or bacteria commonly found in sewage.

4505 In passing my judgment and opinion on the sanitary condition of the water of the Illinois river at or above Peoria I only expressed an opinion in regard to the bacteriological purification at that place and the absence of pathogenic bacteria.

4506 My opinion is based solely and alone on my bacteriological tests with regard to the bacteriological flora at that place and from that bacteriological flora I express a judgment and draw certain conclusions only in regard to the bacterial purification, but not with regard to any other purification. My examination refers purely to the bacteriological side. You do not determine the sanitary condition of any water purely by bacteriology. You only determine the bacterial pollution of a river or lake water by bacteriology and not any other element. Bacteriology has nothing to do with the final judgment. We leave that to the sanitarian to decide upon all the factors which he has collected from all different science. A water may be bacteriologically pure and may be chemically impure and vice versa.

Q. Now then, Professor, confining yourself to bacteriology and confining your opinion and judgment and your con-
4507 clusions as to the sanitary condition of the water in the Illinois river at Peoria and at other points, I want to ask you if it would not be necessary before you could express a reliable and adequate conclusion as to the condition of that water for you to first have a bacteriological analysis of that water from one end of the year to the other end of the year to

the other, taking into consideration the various changes in temperature, cold weather, hot weather, warm weather, flood times, low water seasons and local conditions from one end of the river to the other, and if it is not necessary to have all this information. What is there in the analysis which you have made, which leads you to believe and which furnishes you sufficient information to pass judgment upon that water?

A. I did not pass judgment on that water. I examined a number of specimens between February and October from each place and mainly for the presence of pathogenic bacteria. I was not to pass judgment on the potability of the water, but I was to determine during this period what pathogenic or disease producing bacteria could be found in the specimens submitted to me for examination. As to the rest of the question, I am willing to say that the more numerous the examinations the better the final conclusions are. There is no doubt that 10,000 examinations are better than ten. The necessity of having the water examined bacteriologically at all seasons of the year is another point that is desirable.

4508 When I stated on direct examination that the sewage of Chicago has no influence whatever on the sanitary condition of the water in the Mississippi river at the Chain of Rocks, my opinion as to the bacteriological purification of the river was based on the findings in this report to the State Board of Health.

Q. I will ask you this question, professor, if you did not state a few moments ago that in determining the sanitary condition of the water from a bacteriological standpoint that it was necessary for you to take into consideration the temperature of the water at all seasons of the year, the stage of the water, the flood seasons, winter season, summer season, the extent of the polluting material entering that river, and that you stated you had not taken such facts into consideration in forming these conclusions?

A. Yes, I have not. I did not determine the sanitary condition of the water. I determined the bacterial purification.

(Witness is asked hypothetical question involving conditions alleged to have existed prior to opening of canal, in Chicago river and the Illinois and Michigan canal.)

4509 A. I will simply say that in a long canal, 30 miles long, sewage entering and remaining more or less stagnant, will allow the same multiplication of saprophytes that we find here in the drainage canal and the same destruction of pathogenic bacteria. If there was greater concentration of polluted matter in the Chicago river prior to the opening of the canal than there is now in the main drainage canal, as to whether such conditions would be more or less favorable as to the vitality of pathogenic germs, I can answer that in a general way. If you take a gallon of water and dilute it with a pint of sewage the conditions for the disappearance of pathogenic germs would be more favorable in that composition than it would to take a barrel of water and dilute it with a pint of sewage. Assuming that the same amount of sewage is discharged into two streams, one with a flow of 35,000 cubic feet per minute, and the other with a flow of 250,000 cubic feet per minute, I will say that the greater the dilution the farther separated, of course, will be the pathogenic germs and the less will be the bad effect upon the rapidly multiplying saprophites and their products and therefore as a general proposition a pathogenic germ ought to live longer the purer the water, but in the larger stream the dilution would be so much greater. The greater the dilution the farther apart will be the individual bacteria and the less effect the growth of the saphophytic bacteria exert on pathogenic germs.

(Witness temporarily withdrawn.)

4511 W. E. LAUTZ, examined in chief by Judge Springer:

4512 Was employed to take samples of Illinois river water for drainage canal commission at Pekin, Illinois. (States places where samples were taken and method employed.)

4515 The sewage of Pekin entered the river above the point where these samples were taken. There was a complete mixing of the Peoria sewage in the water. I know that the

Pekin sewage was not mixed with the water. It was in the fall of the year that I took these samples and the sewage was of a higher temperature than the temperature of the river water. You could see the steam arising from the sewage in the water along the Tazewell county shore of the river and hugging that shore all the way down.

4516 Tazewell is on the east side of the river opposite from where I took the samples.

4520 PROF. F. ROBERT ZEIT, resumed the stand for further cross-examination by Mr. Jeffries:

(Witness states extent of his study of pathology and causation of diseases, etc.)

4522 I have also studied the behavior of pathogenic or disease producing bacteria in water. I found that when pathogenic bacteria are put into water containing much organic material, and polluted with sewage bacteria, or containing many water bacteria, and the mixture is kept at a low temperature, as low as ten or twleve degrees centigrade, the water bacteria multiply rapidly and the other saprophytic bacteria multiply and overgrow the pathogenic bacteria which then die out quickly. If the temperature is somewhat higher, say the temperature of the room, the other conditions being the same, the saprophytes grow—multiply most and overgrow the pathogenic bacteria to such an extent that they disappear also within several days. When the pathogenic bacteria are put into pure water—I mean sterilized water, containing no bacteria of any kind, they will live for weeks.

Q. Four weeks, you say, or for weeks?

A. For weeks—three or four weeks even, even if there is no organic material present. If there is a slight amount of organic material present, and the temperature is favorable, they will even increase and they will live in there for weeks. If we take pathogenic bacteria and put them in a so-called pure potable water, a water containing no saprophytic bacteria, but only water bacteria, such as are commonly found in water, innocent water bacteria, and keep the temperature at that of the

water or even at that of the room, there is a great multiplication of water bacteria only. I am speaking now of a water which is almost free of organic material. Water bacteria seem to be able to grow more rapidly even in the absence of any organic material, whereas saprophytes will grow better and increase more when organic material is present, so that even in a pure water where there are no saprophytic bacteria present, a rapid multiplication of the common water bacteria takes place and the pathogenic bacteria are overgrown and disappear. The experiments that I have made were mostly with Lake Michigan water and also with sterilized water, and finally they were made with the waters of the Illinois river above Grafton, with the Mississippi river just before the Illinois enters it, and
523 of the Missouri above the mouth of the Missouri. Those three waters contained great numbers of saprophytic bacteria and the pathogenic bacteria died out quicker than they did in Lake Michigan water.

JUDGE SPRINGER: Can you state within how much time?

A. In five to six days. I might add here, that I also know this to be a common experience. For instance, in the water of the river Ganges and the river Yumma, which is very rich in organic material, the vibro of Asiatic cholera will die in two to four hours, according to the experiments of Hankin. I have in none of my experiments found any such conditions. The shortest periods of life I have observed were five days in the waters that I have examined. (Witness states where and how the typhoid bacillus cultures were obtained that were used in these experiments.) The typhoid bacilli used in the experiments were the fifteenth to the thirtieth generation, possibly more in some instances.

524 In passing so many generations they no doubt lost some of their virulence, but they were still alive. They might grow even better in the later generations, although they lost their virulence entirely. They may be alive and show all the characteristic bacteriological factors by which we recognize the

typhoid bacilli even if their virulence was lost. The problem was not as to whether it would lose or increase its virulence in that water. We cannot keep the typhoid bacilli alive in the laboratory for a number of years. (States manner in which they may be kept alive for a short time.)

4525 A typhoid bacillus is a parasitic organism. It lives only too well on the broth that we use. It will multiply at such a tremendous rate, if the temperature is that of human blood that it will kill itself by producing substances that are poisonous to itself. As grown in the laboratory it is a saprophyte. As applied to the system of man it is a parasite. It is a parasite at no other time.

4526 A typhoid bacillus coming from the patient is not more hardy than one cultivated in the laboratory. We frequently find that a parasitic germ will grow much better after it is grown a few times as a facultative saprophyte. We find sometimes that we do not get as hardy a form from our cultures as we do from new cultures. I stated that pathogenic bacteria died in five or six days in the presence of large numbers of saprophytes at a temperature of between 10 and 12 degrees centigrade. If these conditions are changed and the saprophytes are absent, or the temperature is changed, they will live longer.

4527 Increase of organic material in saprophytes decreases the life of the typhoid bacilli. I stated last Saturday that in my experiments I made the conditions identical with those in the river, except in one point—that in the laboratory experiments the products of the saprophytes have remained in the culture or in the water with the typhoid bacilli, whereas in river water they would be diffused.

4528 The bottles were stopped with cotton, which allowed the oxygen of the air to be present upon the water. I cannot state any definite figures as to the amount of oxygen in the river and in the bottles. There may be some difference and there may not.

4533 Colon bacillus would probably not produce disease if it was swallowed, but would do so if it entered the tissues in large numbers from the intestines. As to the swallowing of colon bacilli, this is in my opinion, not pathogenic. In fact, it has been advocated recently for the cure of chronic constipation to drink pure cultures of colon bacilli. Those who believe in that sort of treatment might go to the drainage canal. The colon bacillus is not pathogenic unless it is virulent. It is always considered more or less pathogenic when found anywhere in the body except in the intestines. It is a facultative saprophyte.

4534 We find that some organisms appear to be purely parasitic organisms, and do not grow at all on dead organic material, so that is an obligate parasite, whereas, we find that a number of the disease producing bacteria can be made to grow on dead organic material, so those can be accustomed to live as saprophytes, that is on dead organic material. I think we ought to draw the line between the two and we ought to say that there are some bacteria that grow only on living organic material (obligate parasites) and then there are some that live only on dead organic material and are destroyed immediately they are injected into the tissue of man or animal (obligate saprophytes) and then there are some that stand between those extremes, favoring the living organic material but capable of existing on dead organic material (facultative saprophytes.) The typhoid bacillus is a facultative saprophyte and has the faculty of growing on dead organic material. The cholera vibrio the same. Neither one of them, however, occurs in nature, and whenever found, it must have come from the intestinal canal of a case which had the disease. Both of these germs require for their multiplication organic material. They may live in the absence of all organic material for a short time. The proper kind of organic materials will produce a better growth.

4535 I have examined other waters bacterially for the presence of pathogenic germs than those that I have testi-

fied about. I have examined numerous well waters from different parts of the State, suspected of producing disease.

4536 In making these examinations, we look for all pathogenic bacteria. The injection of typhoid bacilli into a guinea pig will produce death under all conditions, provided the germ is alive, of course and virulent. There is a difference as to the colon bacillus; I do not think the two can be compared.

4537 Injectiong a bouillon culture of typhoid bacilli produced no infection of the animal. The animal dies of the poisons of the typhoid bacilli, so it is a toxic effect. All animals are immune to typhoid fever. If you inject colon bacillus in bouillon culture in large quantities, you can also kill the animal by the poisons of the colon bacilli but usually a virulent colon bacillus will cause an infection and the animal lives for about five or ten days then dies with septic peritonitis. It is possible that a water might be perfectly harmless for drinking purposes and yet contain properties that would kill a guinea pig if injected into it. That is the reason why we attach so little importance to the cases where the animal dies promptly. The value of that test is mainly this, that is the animal can live after such a test that it is pretty certain that that water will not be injurious to the person who drinks it. If such a severe test does not have any effect on a guinea pig, then I think it would be perfectly safe to drink such water from a bacteriological standpoint.

4538 We also made plates and determined pathogenic bacteria from the plates and consequently if there are no pathogenic bacteria present, an animal might die anyway of the disease produced by saprophytes. Waters which are teeming with saprophytes usually are found by the chemical test to be very bad, that is the reason they are condemned. We must judge the potability of water by three tests: First, the physical characteristics of the water may be bad; if they are not bad, then the chemical characteristics may be bad, and if both of these are good, the bacteriological character of the water may be such as to condemn it. If the bacteriological character

is good and the others bad, of course I would condemn it on other grounds than purely bacteriological grounds.

4541 I have examined the water in wells that have been charged with being infected with typhoid bacillus. In my examination of that water I never discovered any typhoid bacilli. I have not in my investigations of any typhoid infected water ever been able to discover the typhoid bacillus except in laboratory experiments when I infected water with typhoid bacilli. I had an excellent opportunity at one time. It was in Wisconsin where about sixty cases of typhoid occurred in a small hamlet, which all seemed to be traced to drinking the water of a certain well after the arrival in this little hamlet of one person who had been injected with typhoid fever several hundred miles away. In that particular instance it was almost certain that a certain well had been polluted with discharges of this case and was a source of infection in all the cases but at no time was I able to find any typhoid bacillus in this well water. I think we were reasonably certain that the water in that well was typhoid infected, because people who drank from other wells in the neighborhood were not infected. I reasoned that the time of incubation had been sufficent to allow the typhoid bacilli to disappear from the well water. What became of the typhoid bacilli in this well water? Why weren't they there any more? If we figure that it takes two weeks to infect, it almost seems as if those weeks had been enough to wipe out the typhoid bacteria that must have been in there, to judge from the whole history of this epidemic. I believe the cause why we did not find the typhoid bacillus is, aside from the difficulty of finding it in small quantities of water, that we never examined that water until the epidemic had already existed for several weeks and after that the typhoid bacilli seemed to have disappeared. Most of the investigators who examined water in districts where the typhoid infection seems to have been postively traced to the water supply were unable to find them any more. I examined the water several weeks after the epidemic had broken out. We

condemned the water on suspicion before I examined it. After I examined it, I told them not to use the water but they did use it. It was finally proven that our warnings were not
4543 heeded. This epidemic ceased just as quickly as it had come, after 60 or 80 cases I think had all run their course. It was clearly brought there by one case that came home ill and everything started from that well. The name of this place is Little Black, Wisconsin. It was ten or twelve years ago.

4544 It is pretty hopeless to examine water for typhoid bacilli. The bacteriological examination for disease-producing bacteria is a better test than the experience of the people who use the water for domestic purposes.

4546 If I were told that the water in a well is typhoid infected, because the people who drink it were made sick of typhoid fever, I would condemn the water on the experience you mention just the same as I would condemn any river water that was not filtered, for the use of any city, even if it had not received sewage.

Q. I want to know whether or not you would put more reliance upon your bacterial analysis of the water than you would upon the effect of the water upon the people who drank it, if its effects were known?

A. I think that if I was able to make such a test, an animal test as I have described, with that water, without producing any effects upon the animal, whatever, I think that I would be willing to drink that water.

4547 That is not excluding even the presence of small numbers of typhoid bacilli in the water. If it had been the supposed experience, even the suspicion that the water was the cause of an epidemic I would prohibit the use of that water on suspicion. The experience is no test. It is only a safeguard against suspected danger.

4549 The Chicago sewage would not be drank. I judge if there was so much organic matter in the water there would also be large quantities of saprophytic organisms which could

produce substances and bring about intestinal diseases, aside from any pathogenic bacteria.

4552 If pathogenic bacteria are in the water and have not died there yet, they will be distributed and separated more or less by dilution according to different conditions existing for dilution, and then require mostly, for their pathogenic effect, of first meeting with a favorable temperature, and favorable culture media, before they produce an infection. If a very pure water and a very potable water is infected with pathogenic bacteria, a water tolerably free from organic material, they would live longer than in a badly polluted water with much organic material. Now, even under the latter conditions, there would be a large separation by dilution, which is probably the reason why we do not find them, so they would be separated so far apart from each other that in order to produce an infection it would be necessary that they should first meet conditions favorable for multiplication. Take the case of the typhoid bacillus, one germ might be in a barrel of water and if that one germ happened to get into a milk can, during a hot summer day, for 24 hours perhaps, this bacillus would find in the milk a favorable culture medium, and the persons drinking that milk would drink a culture of typhoid bacilli; whereas, one would have to drink all that water to get one bacillus, and further one germ alone would not produce infection. Numbers are very

4553 essential to produce an infection. In order to produce typhoid fever the germ must be swallowed, it must be virulent; it must be swallowed in great enough numbers and even then the resistent forces of the organism must be decreased. We see occasionally, where the infection has been traced to milk, that some people partaking of it develop typhoid fever and others do not. Assuming a discharge of 250,000 cubic feet of water per minute through the Drainage canal since its opening and that prior thereto the sewage of Chicago passed through the canal at the rate of 35,000 cubic feet per minute, I should judge that the less the dilution the more rapid will be the mul-

tiplication of saprophytes and the destruction of the organic matter. In other words, if you have much organic material, you favor the growth of great quantities of saprophytes, and they dispose of the organic material more rapidly than if you spread them over large areas and allow the saprophytes to attack it there.

Q. State, professor, what difference there would be in the longevity of pathogenic germs, or disease-producing germs in those two streams of water which I have just mentioned?

A. I will say what I have said several times, that the more organic material there is, the more rapid the destruction of the pathogenic bacteria, so the dilution of the organic material does not increase the rapidity of destruction of pathogenic bacteria. In fact, it would rather tend to decrease it. If we place pathogenic bacteria in sterilized water, where no other bacteria are present, they live longer than if we put them into the worst sewage contaminated water. The purer the water the longer the life of the pathogenic germ. By purer I mean less organic matter, therefore less saprophytes.

4554 Two streams flowing side by side, carrying sewage from Chicago, the one existing in a diluted condition with a flow limited to 250,000 cubic feet of water per minute, the other limited to a flow of 35,000 cubic feet per minute,—the disease-producing germs would disappear much more rapidly in the smaller stream than in the larger.

(Witness temporarily withdrawn.)

WILLIAM S. SAYER, examined in chief by Judge Springer:

I live in Chicago and am employed by the Kennicott Water Softener Company. I am a graduate of Beloit College and also attended the University of Chicago, where I studied chemistry and bacteriology.

4555 In 1901 I was instructed by Dr. Jordan, under the direction of Mr. Irons to go to Grafton and establish a laboratory. From Oct. first until about the 25th of December, we

made daily bacteriological analyses of the water of the Mississippi and of the Illinois rivers. Samples from the Illinois river were taken about three miles from the mouth of the river.

4556 The Mississippi river samples were for the most part taken near the Government dock, near the mouth of the Illinois. (States how samples were taken.)

4557 The principal determination was a count and enumeration of the bacteria developed on gelatine plates. The results of the examinations were indicated on blanks which were provided for that purpose.

4558 The blanks that are handed to me are the ones which I used for that purpose. I did the writing myself. These tables are correct determinations of the results which I obtained from the examinations which I made during that period.

4559 It requires all of these sheets to correctly set forth all the bacteriological examinations that I made. There was also as what is known as fermentation tests made. When these sheets shall be presented by Dr. Jordan with my signature, as it is here, they will contain the fermentation tests that Imade at that time. (Sheets marked "Defendant's Exhibit F," for identification, sheets No. 1 to 18 and agreed that the witness may hereafter draw conclusions from these records as if they were set out in extenso.)

4563 PROF. F. ROBT. ZEIT, resumed the stand for further cross-examination by Mr. Jeffries:

Q. Assuming, professor, that all the sewage of the city of Chicago was discharged into the Illinois river in a diluted condition, or in a diluted state of sewage and water amounting to a flow of 35,000 cubic feet per minute, what effect would the addition of 250,000 cubic feet of water per minute have upon the life and longevity of disease-producing bacteria contained in the sewage of Chicago?

A. The greater the dilution the longer the life of pathogenic bacteria, but as to the possibility of infections, the greater the dilution the less the possibility for direct investion on ac-

count of the greater dilution. If you turn a thousand
4564 typhoid bacilli from a case of typhoid fever into a badly polluted stream with very much sewage, then they will die sooner than if you pour a thousand bacilli into a stream that does not have sewage otherwise, except from the discharge of the typhoid fever patient. The more water, the greater the dilution; the further will be separated the individual bacilli, and therefore, also the less the danger of direct infection by the typhoid bacilli, on account of the smaller number. A typhoid bacillus will live longer in water not seriously polluted by sewage than in another water that is seriously polluted by sewage.

4565 Q. Now, professor, would not the addition then of 215,000 cubic feet per minute, have some effect upon the zone of purification in the river?

A. You are asking me again questions on sanitation, not purely bacteriological questions. A river water of sufficient quanitity to dilute the sewage water fifteen times with a flow of at least six-tenths meter per second permits sedimentation banks of sewage to be formed. No putrefaction or stench forms, which, however, is the cause in the Drainage canal, no algae or fishes are destroyed, which is the case in the Drainage canal. The chemical impurities become insignificant as the dilution becomes greater than the ratio given and the bacterial impurities, of course, remain longer, but also disappear in what I have been terming here, the purification zone.

4566 Q. Then, professor, as you add the volume of water you increase the rapidity of the flow, you increase the abilities of life of the typhoid and other pathogenic germs. Now, as you increase the ability of life, and as you increase the ability to flow, do you not at the same time change this zone of purification that you spoke about a few days ago?

A. Yes sir, you change the zone of purification if you do that.

4567 From my own investigation of the matter, I look upon

the Drainage canal as one big sewage tank, even as it is now, with an increased amount of water, and I hardly believe that very much will get out of the Drainage canal in the way of pathogenic bacteria alive, because the conditions are certainly such as to show no lack there of organic material and no lack of saprophytic life.

4568 I consider the Drainage canal as it is at present an open sewer. I made guinea pig experiments with that water.

4569 Some of it was from Lockport, in the Drainage canal. The animals died mainly of proteus infections. The specimen from the upper part of the drainage canal produced a condition of sepsis, and the animals promptly died from saprophytic poisons. Inoculations of specimens of the Drainage canal at Lockport, did not always cause death. The animals which died had proteus vulgaris infections. The proteus injected into the peritoneum of the animal set up a peritonitis usually of a purulent type. The animal had an enlarged spleen and bacilli in the heart blood. One animal died of sepsis, the same as at Bridgeport. There were evidently bacteria present pathogenic to animals in Lockport, not only toxic substances produced by saprophytes. According to that they are not killed out by the water flowing through the canal and they do enter the Des Plaines river. My report showed the presence of this germ, but the proteus usually is not considered as a pathogenic organism to human beings under common conditions when swallowed.

4570 When I say the typhoid germ has disappeared from the sewage of Chicago before it gets out of the Drainage canal I do not say so upon the experiments which I have made with the life of that germ in the water of the canal, but only by analogy of the laboratory experiments and the conditions existing in the canal. I made no typhoid bacillus experiments with Drainage canal water, only of Lake Michigan, Illinois, Mississippi and Missouri river water.

4571 Q. I am assuming now, professor, that in the samples of water that you examined, typhoid germs existed. Was your examination so accurate as to enable you to have detected it if it was there?

A. No bacteriologist is able to do that. We examined 38 samples of water from the Illinois river at Grafton with a view to detecting the presence of typhoid germs. We made

4572 10 to 16 plates for each sample. The water that was actually examined would amount to about 130 cubic centimeters in all.

4573 It is possible to miss the typhoid bacilli on account of dilution. If I had found one typhoid fever germ in each cubic centimeter that I had examined it would have disclosed a greater polluted stream than I have ever come in contact with. If I found typhoid bacilli in the water I should consider that very serious.

4574 My examinations in the Illinois river were made from February to Oct., 1900, and from Oct. 3 to March 11, 1901 and 1902. As to the findings summed up at Grafton, I find the colon bacillus and proteus types and there is no appreciable difference in the kind of pathogenic bacteria found during the two periods. I never made any counts and therefore no comparison can be drawn from these tables as to numbers. The kinds were the same. There is no difference. There will be more of these kinds in spring and summer when more pollution results, due to rains and other pollution. In winter there is no doubt less general pollution than in summer and spring. In other words, there is less saprophytic life in the winter than in the summer. They multiply less in winter than in summer.

4575 The term "purification zone" and "zone of bacterial purification" is not used peculiarly by myself. It is a term which you will find in every modern text-book on hygiene. (Witness refers to European rivers and cities and gives the

distance of the purification zone as heretofore testified to by him.)

4577 In fixing the zone of bacterial purification, they have been determined mainly to find out what effect sewage had on the water, whether it was possible for a river to free itself again of any bacterial pollution which it had received.

Q. Does the science of bacteriology enable you to determine the place in a running stream where it has been freed from disase-producing bacteria caused by the discharge of sewage into that stream?

A. Under the conditions which I have stated here, yes. We are able to state, as bacteriologists, without the aid of chemistry, the exact place where purification is taking place from pathogenic germs. The bacteriologist claims that with the disappearance of the saprophytes the pathogenic bacteria have disappeared, because the pathogenic bacteria will disappear very much sooner in water than saprophytes.

4580 I define the zone of purification by the great reduction of bacteria of all characters.

Q. I will ask you professor, if that zone is not continually changing from day to day?

A. Yes, sir, that zone is continually changing. I would like to give here an illustration of continuously increased pollution and continuous purification. You spoke of the river Dee. This river Dee above Braemar, shows 84 colonies per cubic centimeter, below the old Mar castle; after receiving the sewage of Braemer, 2,829 colonies per cubic centimeter were found. Below at the bridge of Ballater, 1,139 colonies were found. Below Ballater, after the sewage effluent of Ballater has entered the river, 3,780 colonies per cubic centimeter were found, whereas the effluent of Ballater contained from 235,000 to 26,000,000,000 per cubic centimeter. At Kincardine, O'Neil, 938 colonies only were found in the cubic centimeter. After the junction of the river Neil-burne, again 860 colonies were found in one cubic centimeter. The Neil-burne, 12 yards before the sewage outfall

Cumberland, and assuming that from a bacteriological standpoint the zone of purification had taken place in that river ordinarily 40 miles below Cumberland, and assuming further that there was a typhoid fever epidemic in the city of Washington, and assuming that that typhoid epidemic was the result of a previous typhoid epidemic at the city of Cumberland, which discharged its sewage into the Potomac river—

A. That is a theory.

Q. Just wait. This is an assumption. There is no theory about it. I would like to ask you what effect and what bearing the ascertainment of the zone of bacterial purification at a point ordinarily forty miles below the city of Cumberland would have upon establishing the sanitary condition of the water of that river, after it had received the sewage of Cumberland and passed down as far as the city of Washington?

A. If it was proven bacteriologically that at forty miles the bacterial purification and the disappearance of saprophytes, and the consent decrease of the organic matter which it must have contained, according to your assumption, had taken place, then I would judge that with the disappearance of the saprophytes at forty miles in the zone of bacterial purification, not only the saprophytes would have died by that time but that all the other pathogenic bacteria would have died before that time, and that therefore an epidemic of typhoid fever 160 miles away from the source of such pollution, according to bacteriological judgment would have been due to other causes, and that the water, if condemned was condemend on suspicion only, because there has been a typhoid epidemic higher up on the
4584 river. I think that in a case like that it is much more probable that the typhoid bacilli have been brought by a patient, directly and not by way of the water to the city of Washington, 160 miles below.
4585 If we assume the typhoid dejecta of the patients at Cumberland flowed from Cumberland down to Washington and produced the typhoid epidemic at that place and that the zone of bacterial purification has ordinarily been found at a

of the river contained 1,200,000 colonies per cubic centimeter. In Invercarnine, only 950 colonies per cubic centimeter were found, so we have here a reduction in the total of 40,000,000, a rapid pollution and a rapid bacterial purification, and in spite of all these pollutions of sewage containing 26,000,000 germs per cubic centimeter and in the other case 1,209,000 per cubic centimeter, you have finally again only 950 per cubic centimeter.

Q. Where do the bacteria disappear in these instances?

A. At Invercarnine.

4581 Q. What became of it?

A. The organic material which entered the river, with rapid multiplication of the saprophytes, accounts for the increase of bacteria, and as the organic material became less, was consumed, was eaten up by the bacteria. The conditions for life and multiplication of saprophytic bacteria became unfavorable and they died out.

Q. Do you know this for a fact or is this your theory?

A. This is a fact which hold true in all cases, of rivers, that the rapid multiplication of saprophytes corresponds to the great quantity of organic matter present, and that if these great numbers of saprophytes disappear, the organic matter has been consumed.

4582 Q. Professor, do you know of any cases in Great Britain or in the United States, in which the instance of the bacterial zone of purification has been so well established, that the water below it is considered by competent authorities, safe for drinking purposes?

4583 A. The epidemiologist who neglects entirely the bacterial questions and their significance, of course condemns all waters which are polluted, but the bacteriologist speaks of a zone of bacterial purification, due to those conditions which I have mentioned many times.

Q. Professor, assuming that the sewage of the city of Cumberland is discharged into the Potomac river, and that the city of Washington is situated on that river 160 miles below

point about 40 miles below Cumberland, notwithstanding the determination of that zone of bacterial purification, we would prohibit the use of the water and the ascertainment of the zone of bacterial purification would be valueless, but that is a pure hypothesis and I only answer it as such and under the assumption that all that you state was proven.

4587 I do not believe that the zone of bacterial purification will vary within such large distances as 40 to 160 miles, because the disappearance of saprophytes takes place with the disappearance of organic material, and taking the average for the exminations of a whole year, the variations will not be 120 miles. I have never known of a pathogenic germ multiplying in a running stream or in an open sewer.

4589 Taking the water in the stream or the sewage in the Chicago drainage canal, the pathogenic germs will die out more rapidly in cold water than they will in warm water, but that depends upon other bacteria present in the water. I can say nothing definite with regard to that question. In cold water it would depend on other bacteria present how long they would live. In warm water they might even multiply. Many of them will live longer in cold water than in warm water

4590 if the water is sterile. The zone of purification in a river may move up and down, according to the elements of rapidity of flow, the temperature and the amount of water. The zone of purification from the source of pollution should be much less than 100 miles.

4591 In my opinion it may not be more remote than 160 miles.

I stated that the conclusion of the British River Pollution Commission was that there is no river in Great Britain long enough to purify itself from sewage introduced into it, even at its source. That conclusion is not accepted by bacteriologists. According to the experiments I mentioned today of the Bacteriologist Frankland, with regard to the river Dee in July, 1892, that ought to be withdrawn. That conclusion has been denied absolutely in Germany. Some English authorities still continue that prejudice in spite of the work of the bacteri-

ologists. The Germans have made more thorough investigations on this subject than the English people. The statement that no river purifies itself was given up by a good many as soon as bacteriological research proved its incorrectness.

4596 This bacterial zone of purification depends largely upon the amount of sewage in the stream. The more sewage the more rapid the disposal of the disease producing bacteria on account of the overgrowth of saprophytes. The more sewage and the more favorable the temperature for the growth of saprophytic bacteria in that sewage tank, the sooner the disposal of the organic material, and the earlier will be the purification zone. The more sewage with additional increased flow means a change in the position of the bacterial zone of purification.

4597 If there were deposited into the drainage canal the sewage of 3,200,000 people into 500,000 cubic feet of water per minute, instead of the sewage from 1,600,000 people in 250,000 cubic feet of water per minute, the dilution would be the same. The increased volume of water from the lake and the increased sewage polluted water coming through the canal would create a more rapid growth and therefore remove the zone of bacterial purification further down the river. It is not an easy matter to detect typhoid bacilli in sewage. It is a difficult matter to distinguish between typhoid bacilli and coli in sewage. These experiments as to the longevity of typhoid bacilli were made in water at a temperature of 50 to 53 degrees Fahrenheit.

4600 If the experiments had been made with water at 32 degrees Fahrenheit the water would have been frozen and there would not have been an increase.

4601 Slight variations in the temperature of the water have very little to do with the life of pathogenic germs but greater variations, if you take blood temperature, 98, that increases the growth of the typhoid bacilli. As you recede from 98 1-2 Fahrenheit the typhoid fever germ lives longer as a general proposition in colder temperature when no other bacteria

are present. Typhoid bacteria can live a long time in ice. I must modify that. The typhoid bacillus lives best in a high temperature; it multiplies rapidly then, but when it multiplies produces poisons to itself.

4604 As you increase the dilution in a running stream and remove the whole material farther down, you increase the ability of the pathogenic germ to live. If the pathogenic germs should get out into the stream and get free from any saprophytes or saprophytic influence or effect, they would live much longer than they would if they ran their chances in a septic tank. It is a fact so far as I know, that to the water of Lake Michigan has been attributed repeatedly the typhoid fever from which Chicago has long suffered. I wish to say that I do not wish to deny the presence of the typhoid bacillus in Lake Michigan, when there are many cases of typhoid fever in the city of Chicago and when the sewage of such patients is emptied into the lake, but the tremendous dilution taking place in the lake with billions and billions of gallons of water before such sewage can enter the inlets will produce such a tremendous dilution and spread of typhoid bacilli that the one who drinks this polluted water is not liable to be infected directly because only very few typhoid bacilli could be swallowed in this way. The dilution in the lake would be much greater than in the canal and much greater than in the Illinois river.

4605 It is my opinion that water is not the direct cause of typhoid fever. Many physicians are under the impression that one germ is all that is necessary to produce typhoid fever, but bacteriologists are trying to instruct their students, as well as physicians in general that it is not true and that a large number of virulent germs must be swallowed before infection results and further that not only a great number of virulent germs is necessary to produce an infection but that the resisting forces of the organism must be reduced. Disease producing germs disappear more rapidly in room temperature.

4606 The temperature of the water in the drainage canal is

very similar to that in the lake. I should judge that the temperature in the Illinois river is lower than that in the lake. The addition of 250,000 cubic feet per minute from the lake would have a tendency to lower the temperature of the water in the drainage canal. The temperature in the drainage canal is such as to allow the rapid multiplication of saprophytes as indicated by the gas production which can be seen in the drainage canal, the large bubbles of gas that arise, and as seen also by the great increase of saprophytic life. Those gas bubbles still rise since the canal has been opened. If the temperature was higher there would be still more of a growth of saprophytes and a correspondingly more rapid reduction of organic material and pathogenic germs. Disease producing germs may live in ice.

4607 From my experiments I would judge that typhoid bacilli could live in ice for thirty days. If ice made the journey from the river to the intake tower at the Chain of Rocks in thirty days, it would carry the typhoid germs with it, if they were still alive. Assuming that during the cold snap late in the winter some of the water of the drainage canal containing typhoid germs is frozen into a block and gradually enters the Mississippi river and passes on in it and then melts and mingles with the waters of that river, arriving by the time it is completely melted, on the Missouri shore at the Chain of Rocks, there would be a possibility of the typhoid bacillus, which has not died in this ice, entering the intake, with great dilution of course, but in the first place, the typhoid bacillus ar

4608 riving in the drainage canal would have had to pass through the sewers of Chicago and in the temperature of those sewers there would have been such rapid multiplication of the saprophytic bacteria due to the great quantities of the organic material, that in my opinion the typhoid bacillus never reaches the drainage canal; at least the lower part of the drainage canal and probably not even the upper part of the

4609 drainage canal. In my opinion they are dead when they arrive in the canal, because the sewage in our sewer

system is in a much more favorable condition for the growth of saprophytes than the drainage canal. This depends, of course, upon the length of time the sewage remains in the sewers.

4612 It may be true that if typhoid bacilli lived five, six or seven days in samples of laboratory water taken from the canal that they would live ten or twelve days in the canal proper but the very opposite may be true. It might be similar to conditions existing in the river Ganges. Cholera vibrio live longer in laboratory experiments than they do in this river.

4614 Assuming that there were typhoid germs in the canal and the river flowed at the rate of forty miles in 24 hours, they would get to St. Louis in ten days. If typhoid germs were there and were alive after ten days, they, of course, could get into the intake.

4615 (Witness temporarily withdrawn.)

FRANK WRIGHT, examined in chief by Judge Springer:

Live in Chicago. Am medical student. Took samples of water from the Illinois and Michigan canal from Bridgeport, from the Drainage canal at Western Avenue and from the Illinois and Michigan canal at Western Avenue, in 1899 and 1900. (States were samples were taken and method pursued, etc.)

4621 PROF. F. ROBT. ZEIT, resumed the stand for further cross-examination by Mr. Jeffries:

Typhoid fever bacillus does not form spores. If it did, its longevity in water would be igreater. The spores of anthrax may get into a river, as does the tetanus bacillus. I testified that I found anthrax germs and tetanus germs as well as one of the pus formers, in the Illinois river water, also the bacillus enteritidis.

4622 The spores of anthrax or tetanus bacillus might be washed into the river and exist for many months. Tetanus spores are found in nearly all garden earth and street dirt

and could therefore be washed into a river during any heavy precipitation. Anthrax spores are not commonly found in nature. The spores of tetanus can live for months. Tetanus spores are found usually in all rivers so that it would not be surprising to find them in rivers.

4623 Garden earth and street dirt are more likely to contain those spores. The addition of the street washings of a city containing two million people to a stream such as the Illinois river would be insignificant compared with the large area the river travels and with the large amount of washings that that river would receive from heavy precipitations all along the river. The addition of the street washings of a city containing 1,600,000 people might be the source of the tetanus spore which may be found or which may exist in the water of that stream at any given point below the city. If a tetanus germ be detected in the water supply of St. Louis it could not be determined by examination of the sample of water from which the germ was extracted that its original source was the city of Chicago or some other point along the river.

4624 The contents of the intestines of animals as to tetanus bacilli must be mainly due to the foods that have been eaten and that were soiled with earth, or dirt containing those spores and in that way the tetanus bacilli may be found in the intestines of those animals. My opinion is that it is simply the germ in the soiled food that has entered the intestine in that manner, foods soiled by street dirt or garden earth. If there was a great increase or multiplication in the intestinal canal of the animal, the animal would die of the toxins produced by the bacillus.

4626 Assuming that fifteen to twenty thousand cattle are slaughtered in Chicago daily and that in the intestines of these cattle there is a large number of tetanus germs which find their way by washings from the slaughter houses into the

Drainage canal, it may be true that they will find their way into the water supply of St. Louis, but tetanus is not produced by swallowing the germ. It is produced by inoculation subcutaneously in the form of a wound.

4629 Assuming that a steer with anthrax bacilli or spores in its hair was slaughtered in Chicago and that the washings of the hair and the animal got from the pens of the slaughter house into the sewers carrying with it the germs of anthrax, those germs if they were spores, when they reached the Missouri shore of the Mississippi river at the end of thirty days would be alive and active. They would, if numerous enough, produce anthrax in susceptible animals. The fact, however, remains that such animals could not pass inspection here in Chicago and be slaughtered.

4631 Anthrax bacilli have been found in water occasionally or anthrax spores, and have been supposed to be the cause of infections among cattle through water. That was the supposition because it was known in these cases that infected material had been poured a short distance above, into the river. Both the anthrax and the tetanus in order to produce infections in man are usually inoculated subcutaneously and do not produce infection by swallowing although cases of intestinal anthrax have occurred. In case the spores came from Chicago and were found on the shore of the Mississippi below the entrance of the Illinois, if the cattle there drank large enough quantities of virulent anthrax spores, it would be possible that the animals would develop intestinal anthrax.

4633 My position is that one anthrax germ will not produce disease if taken into the intestines of an animal.

4634 Probably pathogenic bacteria would live a little bit longer in soil and earth than they would in water that was rich in organic material. (As to the bacteria that cause dysentery, etc., and the relative vitality and longevity of other disease-producing germs than those of cholera and typhoid fever, see testimony of witnesses on pages 4634-5-6-7-8.)

4639 (As to how many germs are necessary to cause an infection, their virulence, etc., see pages 4639-40-1-2.)

4647 I stated in my direct examination that I discovered the bacillus enteritidis in the Illinois river. This bacillus produces no spores. It is not the bacillus enteritidis sporogenes of Klein; it is the bacillus enteritidis of Gaertner. Others have found the bacillus enteritidis sporogenes in sewage and have described it as Klein's and claim they have found it in great numbers with spores.

4648 That bacillus may produce disease. It is not commonly described by bacteriologists as a pathogenic germ. I would class it in its pathogenic effect with the colon group.

4649 It would live in the spore form for months and is very resistent. If in the water, they could travel from Chicago to the Chain of Rocks and be still alive. (Witness however states on page 4637 that it was not the bacillus enteritidis sporogenes of Klein but the bacillus enteritidis of Gaertner which produces no spores, that was found by him in the Illinois river.)

4650 If I should find this particular spore or organism in the water that I was examining along with large numbers of colon bacteria, it would have some effect upon my conclusions as to the condition of the water examined. If there were large numbers of different bacteria belonging to the colon class, I would consider that as sewage polluted water.

4651 It is true that pathogenic bacteria in the form of spores can exist in the water for a long time and may be either virulent or non-virulent. Spores may pass down the Illinois river to the Mississippi on the Missouri shore and the intake of the St. Louis waterworks. I think that the majority of bacteriologists are pretty well agreed that typhoid bacteria can live but a short time in water, as well as sewage, and shorter in sewage of course than in water and that they live the longer in water the purer the water and the more free the water is from saprophytic bacteria and water bacteria.

4652 Some men have found that with water bacteria only, they live for 20 days; or that typhoid bacilli live in water 20 days, 30 days, providing the water is not badly polluted by saprophytes. Others have found them to die very much earlier. I believe that all competent bacteriologists are agreed that typhoid bacilli in the presence of large numbers of water bacteria and saprophytes at low temperatures, have no opportunity of existing there more than for a number of days.

4653 These experiments were all made in the laboratory. I will admit that it would probably live longer in running water if those saprophytic products were not present but were capable of being removed. As to the time, I think it has never been determined by any one what the difference would be between the laboratory experiment and the actual experiment in the river water. I stated that they would live for a number of days in the laboratory experiments. In my experiments the shortest time was five days when I was unable to find them. In Lake Michigan water the shortest time was in one case where there were many colon bacteria—six days, and in the others where there were many water bacteria, ten days, and the longest that I found them in very pure Lake Michigan water at room temperature, eighteen days.

4655 The same may be true as to the cholera vibrio. Their longevity depend upon the organic material and the other bacteria present and the temperature. In sterile water it is a fact that competent observers have found cholera germs alive for a period of seven to fifteen and twenty days, and even for three months.

4657 Assuming that the germs of cholera live in sewage and river water as long as 13 days and that cholera should appear in Chicago and that the germs were discharged into the Chicago Drainage canal they might arrive at the Chain of Rocks if they were not killed before.

4658 Even if they did arrive there we would again have to consider the same conditions which I have mentioned

so many times. That is the germs would have to be swallowed in sufficient number, they must not have lost their virulence, and the resistant forces of the body must be reduced because Professor Pottenkofer swallowed fresh bouillon cultures of the cholera vibrio, the Asiatic cholera vibrio, repeatedly, to bring the experimental proof that if the resistant forces were normal, you could not produce Asiatic cholera. In my opinion there cannot be conditions existing within the human system that would produce the culture and growth of cholera germs from one germ, and that growth continue until the patient finally becomes sick of the disease. In my opinion, it is necessary to decrease the resistant force of the human organism. It is also necessary that the germs be virulent and that a sufficient number of them be introduced to produce the disease. If one or more of these factors is absent the disease is not produced.

4660 When Pottenkofer drank the bouillon culture of Asiatic cholera, he did not develop Asiatic cholera, but he had vibrios in the stools, but it is shown thereby that even a great number of the virulent germs is not sufficient to produce the disease when the factor or reduced resistant force is absent. All the factors have to be present to produce infection. Pottenkofer was in excellent health at the time. He did not diet and prepare himself for the test. The only proof at that time that the germ alone was not everything, that the other factors which are recognized today in bacteriology, all played an important part, first, the germ; second, the number must be great; third, the resistant force of the organism must be reduced, and fourth, the germ must be virulent, and only when all factors are right an infection takes place. Typhoid and other pathogenic germs, survive longer in purer water than in the more polluted water. If the dilution of the Chicago sewage should, at any time, become greater, more water of Lake Michigan being mingled in any way with it, it is also true that the pathogenic bacteria will tend to survive longer. It is true that the greater the dilution the longer will be the life of the typhoid bacillus, but at the same

time also the greater will be the dilution or separation of typhoid bacilli which entered that water, so that a given quantity of water will also contain a smaller number of typhoid bacilli.

4662 Typhoid bacilli can grow upon food or vegetables at the ordinary temperature of a room but they do not multiply as rapidly as they do at body temperature. It multiplies rapidly and readily on vegetables on a hot summer day but they would not multiply in the winter or spring.

4663 Q. Then, professor, on your theory of no direct infection from drinking water, at what season of the year should typhoid fever be the most abundant when derived from drinking water?

A. The season has nothing to do with it. If water that contains very few typhoid bacilli should get into the milk and the milk into the household, and the common temperature of a room in the household, even in winter for that matter, should be favorable, the typhoid bacilli can multiply. There will be a culture of typhoid bacilli in that milk, and persons drinking that milk will drink a culture of typhoid bacilli. I realize that the seasons for typhoid fever are the spring and fall and not very much in the summer. I have seen typhoid fever all through the summer.

Q. But on your theory, professor, assuming that typhoid fever is always present in the same quantity in the water that is being used, wouldn't it be natural to believe that there would be more typhoid fever in the summer than at any other time of the year?

A. I have also an explanation for that. The reason why there are less cases of typhoid fever in the summer than in the spring and fall is because in the summer the temperature of the water is more favorable to the life and growth of saprophytes, and if any typhoid bacilli do get into the water, they are rapidly overgrown by saprophytes, more rapidly than in the fall and winter when the temperature is low. I realize that my theory is perhaps not quite accepted by some epidemiologists, but I

have reasons for it, which are entirely based upon the biology of the germ, and its behavior when it gets into competition with other bacteria, such as water bacteria and saprophytes, as observed in the laboratory experiments stated. There can be no such great and essential differences between laboratory experience and the behavior of typhoid bacilli in nature.

4664 I do not believe that many of the leading pathologists, epidemiologists, bacteriologists and sanitarians are opposed to my theory of indirect infection. I believe that most epidemiologists admit the great role and importance that this indirect infection plays in the epidemics of typhoid fever. The one point in which I think I differ from many epidemiologists is that I do not believe there is such a thing as direct infection from drinking water. In view of what I know of the biology of the typhoid bacillus, I cannot see that a direct infection can occur, except perhaps under the following conditions: If the excrement of typhoid fever patients containing millions of typhoid bacilli should get into a well, where there is little water, and other persons drinking that water should develop typhoid fever, then it would seem evident that in that case, due to the great number of bacteria swallowed in that way, there was a direct infection from water. I certainly admit that, but I am speaking here in regard to conditions that exist in Chicago, where a large body of water, Lake Michigan, receives sewage polluted material containing typhoid bacilli, or in the Illinois river water, after the sewage of Chicago enters the drainage canal. Even if no saprophytic life whatever should occur and typhoid bacilli should be able to exist until they reached St. Louis, there would be such a tremendous dilution with billions and billions of barrels of water, and the distribution of the individual bacilli to such extent, that they could not, if they did arrive there, produce a direct infection because their number would be too small and only by finding in milk or food supply and favorable temperature conditions a possibility for multiplication sufficient to produce infection.

4666 The history of the last Chicago epidemic illustrates bet-

ter than anything else I know, that my opinion is the correct one, because the district that had the greatest number of typhoid fever cases was the district receiving the purest water from Lake Michigan; in other words was the district that received the water from the Four Mile crib, whereas the district receiving the water from the Two Mile crib, much nearer to the shore, had no typhoid fever at all. The district which had most of the cases of typhoid fever here in the city evidently may have used the water which contained typhoid bacilli in a greatly diluted condition. Now if the dilution of the typhoid bacilli had been equal all over the lake, why is it that the people that were drinking the water from the Two Mile crib should not have had typhoid fever, if it was direct infection, why should they not have had more typhoid bacilli and more cases than the district receiving the water from the Four Mile crib? The fact was that Hyde Park had very few or no cases of typhoid and the poorer district, supplied with the purest water of Lake Michigan, had all the cases of typhoid fever. In that poorer district, the water reached decomposing vegetables, and did get into the milk supply of that locality—these people were too poor to buy ice and keep their various food products in the best condition.

Q. And too poor to boil the water also?

A. And too poor to boil the water also, and the result was that if there was one typhoid bacillus in one barrel of water one could have drank the whole barrel without becoming infected, but if that one bacillus happened to reach the milk supply or food materials and was exposed to a favorable temperature it multiplied and these people then simply swallowed cultures containing millions of typhoid bacilli. Now, if it were direct infection by drinking water, why did not the people who used water from much nearer the shore, where there was supposedly much more sewage, why did they not have typhoid fever? Because they were people living under the best of sanitary conditions, using only the best of foods, preventing any multiplication or growth of typhoid bacilli reaching their milk

supply or food material by way of lake water, which may have contained them in small numbers, by refrigerators and so on. Assuming that one bacteria would be capable of passing through the drainage canal without being destroyed—which in my opinion is impossible—if it got into St. Louis and should find itself in a barrel of water and then find itself on some vegetable at room temperature, or in some media, it would multiply and if virulent it would affect those with decreased resistant force.

4674 If the drainage canal today is a septic tank, the effect of the discharge of 250,000 cubic feet of water per minute from Lake Michigan through that canal, as much as I can see, is only that of dilution, and removing some of the objectionable features with regard to stench, it removes some of the septic operations but the septic operations and the disposal of pathogenic bacteria by rapid multiplication of saprophytes need not be carried to such an extent as to produce a nuisance by producing stench. There is no doubt a point between extreme dilution and stench where the same process will go on, the destruction of organic material, by saprophytes, and with it also the disposal of disease producing bacteria and where at the same time, by dilution by lake water, the other objectionable features, such as stench can be removed. The septic operation might remain complete in the drainage canal even without destruction of the fauna and flora of the Illinois river, and the animal life, I will say, of the river. The addition of the 250,000 cubic feet of Lake Michigan water per minute in the canal has, by dilution, reduced the septic operation but not stopped it. The introduction of this 250,000 cubic feet of water per minute reduces the multiplication of the saprophytes and reduces the time limit for ultimate destruction of all organic material that is contained in the sewage of Chicago and discharged into the canal but at the same time it is not of such an effect as to allow pathogenic bacteria to remain, because there are no fish and no algae capable of living in the drainage canal. Therefore the action of saprophytic bacteria upon sewage and organic material in the drainage

canal in spite of the great dilution that you speak of, has not been affected, so that I would say that the operation in the drainage canal, even with this large body of water that is turned in, is perfect as far as the multiplication of the saprophytes is concerned and its septic tank action.

4677 Assuming that the typhoid germs prior to the opening of the canal remained in the Chicago river for weeks and were then flushed into Lake Michigan and caused typhoid fever in Chicago, as to whether the facilities for such germs getting into the Illinois river are better today than the facilities for their discharge into Lake Michigan prior to the opening of the canal, I will say that according to my view it is impossible that the typhoid bacilli can remain for weeks in the sewage polluted Chicago river, but granted that they were still alive, they would have even then a shorter way to travel into Lake Michigan, than they would have through the drainage canal and therefore there would be more certainty that they had been alive and remained alive after they once entered Lake Michigan, than they would when they entered the Chicago river, or entered the Illinois river.

4678 Q. But, Professor, were not the facilities for destruction of the pathogenic germs remaining in the Chicago river with scarcely no current, for days and weeks, more readily produced than in the drainage canal today?

A. Yes, I think that is true.

4679 Q. That is exactly what I want to get at.

A. In other words, the sewage was present for a longer time without any current whatever, and therefore had a longer time to destroy other pathogenic bacteria.

Q. Then to that extent their ability to get into Lake Michigan would not be so great as their ability to get into the Illinois river, by means of the canal, because of having remained in the stagnant sewage of Chicago, in the Chicago river, for days and weeks?

A. They would have disappeared in both cases, according to my view. Assuming that they got to Lake Michigan in the

one case and into the Illinois river in the other case, the condition as to their reaching the Illinois river would be the more favorable because the saprophytic bacteria would not be as numerous in the Drainage canal, that is answering still on the assumption made first. Assuming that the sewage of Chicago would remain in the Chicago river for days and weeks before it was discharged into the lake or into any stream, and assuming also that the sewage is now discharged into the Drainage canal with the present flow from Lake Michigan and that it
4680 requires only 24 hours for the water to run from the mouth of the Chicago river at Lake Michigan to Bear Trap dam, for that distance and that flow the best place for the disappearance of the pathogenic bacteria would be in the Chicago river prior to the opening of the canal.

4682 As a general proposition, I believe it is true that the greater the flow of the river the less the opportunities for sedimentation of bacteria. There is more sedimentation in the lake than in the river with the rapid flow.

4684 It is possible that all the pathogenic bacteria would be destroyed in the Drainage canal excepting perhaps the spores.

4686 Even if living typhoid bacilli should pass the Bear Trap dam and even if they should get much farther down, they will be constantly exposed again to overgrowth by the saprophytic bacteria and will be constantly exposed to the destructive effects of such overgrowth. Further, the temperature of the water is too low to allow multiplication. The effect of the discharge of 250,000 cubic feet of water per minute in the Illinois river by means of the Drainage canal would effect an increase of dilution. It would have the effect of hastening the journey of pathogenic germs on into the Mississippi river but it would also have the effect of greater dilution and greater separation of the individual germs.

4688 Q. Professor, assuming that all sorts of pollution from the sewage of cities situated upon the Illinois river water-

shed, and pollution from domestic animals were eliminated, so that the Illinois river and the watershed of that river would be in its primal condition; state whether or not, in your opinion, the germs of typhoid fever and other pathogenic germs would not pass from the sewers of Chicago into the Drainage canal, the Des Plaines river, down the Illinois to the Mississippi; assuming that they do not perish in the sewers or in the Drainage canal within two days, within the two days that they are confined therein, if so confined, and assuming further that it requires less than fifteen days for the water to flow from Lake Michigan to St. Louis by means of the Drainage canal, the Des Plaines river and the Illinois river?

A. If all those impossible assumptions were true, the typhoid bacillus would no doubt arrive there.

4689 With nothing else to effect it, except the low temperature, during the fifteen days, if it had been virulent before, it probably would preserve its virulence.

4690 The possibility of millions of typhoid bacilli coming from Chicago to the Chain of Rocks would be absolutely impossible; even if all the typhoid bacilli of all the typhoid cases in Chicago would reach without destruction the Chain of Rocks, the dilution would be such a tremendous one that but very few of them could enter the inlet.

Q. Professor, if that be true, why is it that occasional discharges, and carrying out of the sewage from the Chicago river into Lake iMchigan at the mouth of the Four Wile crib produce typhoid fever in Chicago?

A. Because the one bacillus that might have been in a million barrels of water happened to get into the milk supply of a number of families and produce by multiplication in a favorable temperature millions of bacilli and these people were drinking cultures of them. Such a multiplication does not take place in water.

4691 All the typhoid bacilli that are produced by all the typhoid cases in Chicago, if they were all turned into the

river and if they were not exposed to any conditions whatever of destruction and if they all arrived in the Mississippi at that locality, they would be so far distributed and so diluted through the immense amount of water, that the number of them would be inappreciable, and that it would be a great question whether any of them, even one would enter the inlet at the Chain of Rocks.

4694 I do not like to answer questions which are put on such purely theoretical assumptions and then afterwards be accused of having expressed opinions that are not in harmony with Mr. Jeffries' conviction. I do not wish to go on record as saying that if all the germs or bacteria of all the typhoid fever patients entering the river, if there was absolutely no destruction whatever by any saprophytic bacteria or products, could reach the Chain of Rocks, that none of those that should get there, got into the intake. I stated and want to be understood that the dilution would be such a tremendous one that there would be very few only and that those few would not produce infections by drinking that water containing them. This was the idea which I have expressed right along, of not believing in direct infections with water that contained greatly diluted typhoid discharges, so if you say that I have denied the possibility of any typhoid bacilli entering the inlet under the assumption stated, I have either expressed myself wrongly, or you have misunderstood me.

4698 Q. Then, professor, your position is that infection can be more readily brought about by smaller quantities of bacteria in the water when used in the household for domestic purposes than in the case of large quantities taken into the human system directly by way of drinking the water?

A. Yes, because small numbers of typhoid bacilli contained in the river or lake water could, on favorable culture media, when kept at favorable temperatures, multiply rapidly and produce millions of bacilli. Such infected food would contain millions more of bacilli to the cubic centimeter than well

water which had received the discharges of a typhoid patient. Assuming that pathogenic germs are discharged into the Illinois river from the Des Plaines river and that the Illinois river is frozen over with ice from the mouth to the source and the Mississippi river is frozen over from Grafton to a point at the Chain of Rocks.

4699 The destruction of organic material by multiplication of saprophytes would be slower and the typhoid bacilli, or some other pathogenic bacteria might live longer. Some disease germs would be destroyed by low temperature; for instance, the cholera vibrio dies in ice in a few days.

Q. How about the typhoid germ?

A. The typhoid germ would live longer. Some disease producing bacteria are more susceptible to low temperatures than others. The typhoid bacillus lives much longer at low temperatures than the cholera vibrio. Assuming that typhoid fever germs pass from the canal into the Illinois river and that as they reach the Illinois river they meet a flood.

4700 The flood would mean greater dilution; it would separate them further apart. It would mean more water; it would mean more rapid flow, so they would pass a further distance down the river than if the flow was slower as in low water. The saprophytic life and destructive effect of organic matter would be less. Greater numbers of typhoid bacilli could pass further down the river before they were destroyed.

Q. And if they live from ten to thirteen days, and the water of that flood reached St. Louis within the thirteen days, they might flow on right through, might they not?

A. If they could live thirteen days, which is improbable, because floods carry immense quantities of organic material into the river and immense numbers of other bacteria, which would again take up this competitive struggle. The more the flood the more impurities would reach the river and the more saprophytic bacteria would be present, and therefore, the struggle would be the same. The only difference that I can see is the greater dilution of pathogenic germs and the more rapid flow,

so that less time is given for these competitive struggles to take place.

4701 Pathogenic bacteria die in sunlight in a few hours. In my experiments I excluded the effects of sunlight entirely. I think my experiments were rather more favorable to the life of the typhoid bacillus, than natural conditions in the river.

4703 If typhoid bacilli from whatever source they come, entered the intake of St. Louis, they are capable to produce the same conditions in St. Louis that they would if typhoid bacilli reached the city of Chicago from the Four Mile crib. I mean by this that typhoid bacilli, from any source, entering the intake at the Chain of Rocks, will not produce a direct infection by the drinking of the water, because too small in number, but they are capable of getting upon favorable culture media, such as milk and foods, multiplying at room temperature and producing infections.

4704 Q. Now then, Professor, I will state the question in another way. Assuming that typhoid fever germs will live in the Chicago sewers, the drainage canal and the Illinois river for thirteen days or longer, and assuming that prior to the opening of the Chicago drainage canal, typhoid germs lived in the Chicago river and Lake Michigan for thirteen days or longer, and that they sometimes found their way to the Four Mile crib and after reaching the crib, caused typhoid fever in Chicago among the users of the water from that crib; assuming further that the typhoid germs discharged into the drainage canal since the opening of the canal, enter the water supply of St. Louis within thirteen days, assuming further that the dilution of said germs in the water of the Mississippi at the Chain of Rocks is not greater than that of the typhoid germs in the water of Lake Michigan at the mouth of the Four Mile crib, prior to the opening of the drainage canal, would not the use of water from the Mississippi river at the Chain of Rocks by the people of St. Louis produce as much typhoid fever as would be

produced among the people of Chicago using the water of Lake Michigan drawn from the Four Mile crib?

A. That is true, but the whole proposition has been proven to be impossible.

(Witness temporarily withdrawn.)

4705 FRANCES C. BLANCHARD, examined in chief by Judge Springer:

I reside at Wheaton, Illinois. Am a physician. Was employed by Professor Long to take samples of water from the head waters of the Du Page river.

MR. JEFFRIES: I object to any evidence as to samples of water being taken from the head waters of the Du Page or any of the tributaries of the Illinois river for the reason that any analyses that may have been made of such waters, as applicable to the condition of the water in the Illinois river, is incompetent, irrelevant and immaterial, and for the reason that such evidence will throw no light upon the question as to whether or not the disease producing germs that flow from the sewage of Chicago by means of the drainage canal reach the waters of the Mississippi along the shore of the State of Missouri.

(States where samples were taken, method of collecting, etc.)

4709 PROF. F. ROBERT ZEIT, resumed the stand for redirect examination by Judge Springer:

Mr. Jeffries in one of the questions asked me, assumed that English authors or bacteriologists were more thoroughly informed on questions of sanitation and hygiene and bacteria than the scientists of other countries. The Franklands, authors of a book called "Micro-organisms in Water," a work which Dr. Ravold, in his testimony stated was of the highest

4710 authority, state that the river Dee affords a most perfect example of the repeated pollution and the repeated restoration of a stream to a state of comparative purity. (Objection by Mr. Jeffries to witness reading from book.)

4711 The Franklands state in their book:

"It will be seen from a careful study of the numerous investigations which have been made on the behavior of pathogenic organisms in water, what enormous differences exist in their capacity for living in this medium, that whereas, some varieties are destroyed in a few hours, some will live and flourish for many months. Moreover, it is obvious how greatly in some cases, the character of the water influences the vitality of the micro-organisms, a point which is especially brought out in Trenkmann's experiments with cholera bacillus, and it is of particular interest to note how in the case of unsterilized waters the ordinary water bacteria are able to overwhelm and suppress those foreign pathogenic forms which have been introduced. Krause's experiments are particularly instructive in this respect, for they exhibit the multiplication which takes place in the ordinary water bacteria, and the simultaneous disappearance which ensues of the pathogenic organisms introduced."

4712 The title of the book is "Micro-organisms in Water," by Percy Frankland and Mrs. Percy Frankland, pages 94, 101 and 331. German scientists and bacteriologists have taken the same position that I have stated in my testimony. Other German authors whose works I am familiar with, that I could cite upon that subject are Rubner, Prausnitz and Flugge. Prof. Rubner is considered one of the foremost sanitarians of Europe. (Objection by Mr. Jeffries to witness testifying as to whether or not he stands with others, or alone on the question of longevity of disease producing germs, for the reason that there is no opportunity to cross-examine the persons who are the authors of the books it is proposed to read from, etc.)

First with regard to my position that the indirect infection is the common way of infection of typhoid, and not the direct infection by drinking of the water itself. There are many other ways of carrying the infection from the diseased person to the well, than that by drinking of polluted water. Rubner states:

"It is peculiar that even now days, after we know the biol-

ogy of the typhoid bacillus so well, people cannot separate themselves from the theory that direct infections take place by drinking of polluted water, although it is well known that the typhoid bacillus can be carried and is carried in so many other ways, which would explain the epidemics that arise."

In the same connection, he states that:

"In water, particularly in cold dwater, the longevity of the typhoid bacillus is longer than that of the cholera vibrio (that is the vibrio of Asiatic cholera) but the typhoid bacillus cannot multiply and dies in about six days."

4714 This is page 931 and 930 of the edition of 1900.

The title of the book is "Text-Book of Hygiene, by Max Rubner, Professor of Hygiene at the University of Berlin, and Director of the Hygienic Institute of Berlin." On page 325 he states that, "at the present state of our knowledge it has a certain value to determine, in an experimental way, the relations which pathogenic bacteria have to water. Experiments in which the artificial inoculation of cholera, typhoid, anthrax and pus germs into water was practiced, show that not one of these organisms persists; all of them die in a shorter or longer time. The rapidity of their destruction depends upon (a) the richness or the poverty in organic material. In slightly polluted waters, the quantity of organic material is too small to cause the growth of pathogenic germs. (b) Upon the temperature. In
4715 ice, cholera vibrio died in a few days. The other bacteria named are more resistant. Anthrax spores live a long time. (c) The third condition—the competition with our water bacteria. In sterilized water, which of course, never occurs in nature, all pathogenic bacteria live better. Anthrax spores, cholera vibrio, and typhoid bacilli die in non-sterilized tap-water in a few days, at the temperature of 10.5 centigrade. (d) The fourth condition. The influence of light destroys bacteria. Furthermore, according to the practical conditions, or stimulating practical conditions, Kalinski infected wells with anthrax spores and typhoid bacilli, as well as with the excrements of typhoid fever patients and could not find these germs after one

week. According to these results, it is certain that the bacteria mentioned have no ability of multiplying in drinking water, but may remain alive a few days. The germs have lost a great deal of their danger because they cannot multiply."

Q. Professor, if there were not zones of purification in rivers, and if pathogenic germs were not short-lived, as you have testified, what would be the condition of the rivers in the world in inhabited regions?

A. I think I stated once before that if there was no purification of rivers, such natural purifications of rivers of the polluted material that constantly enters these, the human race would long ago have died out by the overgrowth of pathogenic bacteria. Tetanus is a bacillus found in earth. It is not a water bacteria. It is most commonly found in nearly all earth, practically everywhere where there is garden earth. They may reach St. Louis from Kansas City and other points along the Missouri river in the State of Missouri.

4716 Q. What, Professor, takes place in the human system when typhoid bacilli are taken into the system in drinking water?

A. If the number of typhoid bacilli is small, in my opinion, as I have already stated, no infection takes place. If the number of bacilli is large and they are virulent, and the resistant forces of the organisms are reduced, then infection takes place. If any of the factors are lacking, no infection takes place. Even when large numbers of virulent bacilli are swallowed the resistant forces might be so great as to overcome the infection. In fact, if any of those factors would be lacking, no infection would take place.

4717 I have not made any bacterial examinations of ice for the purpose of ascertaining the longevity of pathogenic bacilli which have been frozen in such ice. According to what I know of the literature on the subject of the experiments of others, the cholera vibrio died in a few days, according to experimental work done by Winslow, under Professor Sedgwick's direction; typhoid bacilli also are destroyed within three weeks

in ice. Although not entirely destroyed numerically, a great destruction of them takes place, and only very few remain after three weeks. The experiments of Hill of the Boston City Board of Health established the fact that typhoid bacilli died very rapidly in ice. Assuming that ice should form in the Chicago drainage canal and the Des Plaines and the Illinois rivers should be frozen over as far down the stream as Peoria and should continue frozen from six to eight weeks and the ice should be broken up and float down the river, being obstructed as is usually the case, in its flow by ice gorges and dams in the river, and assuming that typhoid bacilli should have been frozen in the ice formed in the drainage canal and that they should be carried in that ice as far as the mouth of the Missouri river and that the ice should melt before reaching the intake at the Chain of Rocks, as to whether such bacilli would reach the intake alive and be a menace to the people who might use such waters for drinking or domestic purposes, I will say that there are two factors which would allow me to express the opinion that no living typhoid bacilli would enter the Chain of Rocks. The first one, the experiments stated with regard to the destruction of the typhoid bacillus at freezing temperatures, if the typhoid bacillus should really be in the ice. The second one, the fact that if typhoid bacilli should really get into the drainage canal by way of the sewage from typhoid fever cases, that they might, by reason of their own motility seek the warmer strata of the water and not rise to the surface where the colder strata of water could be frozen.

4719 They would not reach there alive in either case. In the warmer strata, saprophytic products would destroy them. Assuming that the same conditions exist except that the bacteria contained in the ice were cholera, streptococcus and staphylococcus, I would say that the cholera vibrio would die in a few days in ice. The others would probably disappear, if we can reason by analogy, at least as rapidly as the typhoid bacillus, although I do not recollect from the literature, any experiments with ice as to the streptococcus and staphylococcus. I

can only reason by analogy here, but as regards a cholera vibrio, that is different, that has been determined. Cholera vibrio die in ice in a few days.

4720 Assuming the same conditions with anthrax spores, I can answer that in a general way. Anthrax spores remain alive under the most unfavorable conditions, therefore with anthrax spores, we would simply have the question of dilution and separation in the water, and there would still be spores present. Now as to the infectious nature of anthrax spores we can only again take the actual experience of anthrax infections in general, and the fact that whenever an epidemic of anthrax amongst cattle or sheep has broken out, that it was confined to the immediate neighborhood of such source of infection, and that even where we know that the infectious material containing anthrax spores did get into the river, the cattle and sheep some distance down the river did not develop the disease, only those in the immediate vicinity of the original source of pollution being infected. Anthrax spores can live a long time in water, and we must, therefore, conclude that either the factor of great numbers of infecting bacteria is absent further down the river, due to great dilution, or to the factor of lost virulence of the germ. Where intestinal anthrax amongst animals

4721 could be traced to direct pollution of rivers, the disease was only prevalent near the original source of pollution and not further down the river. Man is not very susceptible to anthrax. We have had infections, but they have been very rare and could not be traced to the drinking of infected water. (Witness refers to the anthrax infection at Black river, in Wisconsin, and states the conditions and circumstances surrounding such infection.)

4722 Assuming that the anthrax spores might pass through the drainage canal and reach the Mississippi river and that cattle should drink the water of that river below the mouth of the Illinois, according to what I know of the literature and of anthrax infections and the case I have just mentioned, I would say that there would be no danger of a direct anthrax in-

fection by the drinking of that water at St. Louis. From what I know with regard to this question, I think the Government inspection is a very thorough one at the stock yards at Chicago.

4723 Assuming that tetanus spores should be deposited or get into the drainage canal and should be carried by ice or otherwise to the Mississippi river, I will say that tetanus spores may remain alive in the sewers and drainage canal and

4724 river, but that the amount of tetanus spores entering the drainage canal and arriving at the intake channel at the Chain of Rocks in St. Louis, would be insignificant as compared with the amount of tetanus spores that would enter the river from all other sources along the river, the Illinois as well as the Mississippi and Missouri; further that the number of tetanus spores from Chicago sewage that would really be capable of entering the inlet at St. Louis, would be absolutely insignificant as compared with the number already present in the streets of the city of St. Louis as well as in any other city, or as well as in any other town all along the river. The tetanus bacillus produces lockjaw and tetanus. In order to produce infection the germ must enter the tissues subcutaneously and at some depth and the wound much be closed hermetically, otherwise the germs cannot grow.

4725 As soon as the germs grow they produce a toxin which when absorbed into the body produces first conclusive movements of the muscles, of the lower jaw, then of the upper extremities, then of the lower extremities and finally death. I have never heard of any case of lock-jaw being produced by drinking water.

4726 If tetanus and anthrax are present in water in their non-spore bearing form, all I have stated with reference to the behavior of pathogenic bacteria in water applies here. As soon as those organisms form spores then of course the spores are not subject to that general rule to which I have testified in the earlier examination.

4727 Tetanus bacilli as well as anthrax will die at least as

soon, if not sooner than the typhoid bacilli in their non-spore bearing form under similar conditions. The cholera vibrio dies sooner the lower the temperature. The stapylococcus and streptococcus die sooner than typhoid bacilli. The pathogenic germs that are spore bearing are the anthrax bacillus, the tetanus bacillus, malignant oedema, the bacillus aerogenes capsulatus. Of the important disease producing bacteria, these are the ones.

Q. Now, Professor, assuming there is a remote possibility that a tetanus spore might be carried from Chicago through the drainage canal down the Des Plaines, and Illinois rivers and a possibility that such a spore might enter the St. Louis intake and the hydrants of the St. Louis waterworks, and the possibility that a St. Louis urchin might moisten his finger with water and then shoot a wad into his finger, thus moistened as aforesaid, as stated by Mr. Jeffries in one of his hypothetical questions, and that such moisture may contain a Chicago tetanus spore, as assumed in one of the other questions by Mr. Jeffries, and that such tetanus spore thus subcutaneously injected into the finger of said urchin may have entered the anatomy of said urchin at a time when his system was susceptible to tetanus infection, and the possibility that said St. Louis urchin might then and there contract the disease of lock-jaw—are such remote possibilities as I have mentioned, in your opinion as a bacteriologist, of such a grave and serious character as to constitute a menace or danger to the inhabitants of St. Louis or of the State of Missouri?

4728 A. I will have to answer that question with No. Tetanus infection takes place when street dirt or garden earth containing numerous virulent germs, enters the deeper tissues and not by water as stated.

RE-CROSS EXAMINATION, by Mr. Jeffries:

I stated to Judge Springer that bacteria would not freeze in the ice as long as they possibly could avoid it by swimming away from where the ice was forming into the warmer water. It is no doubt true that they will swim away from the light as

far as they can and from the saprophytic bacteria and from all other materials and conditions that will not be conducive to their welfare and longevity. They will not move large distances. The motility is not as great as that. As they swim away from the point where the water is frozen they are carried down the river according to the current that happens to exist. If that ice is formed over the whole bed of the river and remains there from six to eight weeks and if the conditions of the water are such as will permit the typhoid bacilli to live from ten to twenty days or thirty days in that cold water underneath the ice, and it only requires either ten or twelve days for the water to go from Chicago to St. Louis, it is reasonable to believe that these germs will find their way during their life time down the entire course of the Illinois river, if the bacilli would live at these lower temperatures without dying and would be alive in St. Louis, of course.

Q. That is, if they would live that long?

A. That is your assumption.

4731 As to how long typhoid bacilli live in ice, has not been definitely determined, if we take all of the evidence from all sides. Some find they die in a short time; others say they only die in great numbers, but some of them remain alive for a longer time. Large quantities will not remain at the end of thirty days. The majority of them will die even according to the experimenters that say that some remain alive. The percentage that will remain alive is an insignificant one according to their findings.

4732 The spore of anthrax can no doubt live for years. I realize fully that it takes a very minute quantity of anthrax material to produce an infection, but in cases of epidemics we hear of no anthrax infections a few miles down the river. Knowing that the spores can live for years and also knowing that such spores certainly must be in the water and upon the overflowed shores of this river for longer distances, although only the animals near the original source of pollution die of an-

thrax infection, I conclude that the factor here, that was lacking, was the necessary number to infect.

Q. May it not, Professor, depend upon the fact that no animal whose system was in a proper condition, swallowed one of those spores?

A. Then they shouldn't have all died nearer the source of infection there, whereas no deaths occurred further down the river.

4733 This anthrax epidemic originated near a tannery in Medford, Wisconsin. Some of the hides used came from Brazil and from China; by the experiments, I believe of Professor Russel, these hides were found to contain anthrax spores. A number of animals just below the tannery had suddenly died and practically all at the same time on the meadows immediately below this tannery. The Black river received the sewage of the tannery and had shortly before overflowed the meadows on both shores of this river. In fact the whole epidemic came suddenly amongst the cattle on the banks of the river, and there was much apprehension among the farmers farther down the river because it had also flooded its banks there. I have a farm a few miles below this tannery on this river, and my neighbors were of course also very much alarmed. Their cattle

4734 were usually on my land, which is simply wild woods, the river crossing it, on both banks of the river there are openings, where the cattle of the whole neighborhood graze, because this wooded land is not fenced in, consisting of virgin forests, whereas all the surrounding land is cleared up. All the herds of the neighbors around there have been grazing on the banks of the river on my lands which are frequently overflowed. This is only a few miles below the tannery, but none of these animals died whereas horses, cattle and sheep died just below that tannery. Horses of farmers living within a distance of half a mile or a mile died. Lawsuits followed by many of the people living below the tannery. This matter was investigated by Professor Russell of Madison, Wisconsin, as the State Bacteriologist. He found anthrax spores in the water of

this Black river below the tannery and he has yet water specimens in his laboratory which when injected into animals produce anthrax showing that there are still virulent spores present. This is now a number of years ago. During all these years there has been no death of any animal, I think I may safely say, one mile below this tannery or farther down the river. This is such a striking case where water can be shown to contain virulent spores and retain them for many years, and yet farther down the river not an animal dies, in spite of the fact that there must have been tremendous pollution with anthrax material of that river.

4736 Under favorable conditions an infection of anthrax may take place in an indirect manner although we know of no such infection. It is possible that the germs of anthrax may be carried into the stock yards and slaughtering houses in the hair and wool of the cattle and sheep and discharged into the drainage canal and thence into the Illinois river, but that condition exists all along the Illinois river.

4740 Assuming that germs of anthrax are deposited in the Illinois river by means of the Chicago drainage canal and that they flow down the Illinois river into the Mississippi and in flood times are carried by the waters of that river into the lowlands, into the various river counties of the State of Missouri below the mouth of the Illinois river and deposited upon the earth, weeds, grass and growing substances and that after the water has receded, these anthrax spores are carried into the food preparation which is brought to a temperature favorable to the multiplication of the anthrax spore, the remote possibility exists that the cattle, horses and sheep of said counties, feeding upon such food might become infected with the disease of anthrax, although all the history with regard to epidemics of anthrax and their spread would be opposed to the spread of anthrax in that way. Such spores, if carried on to the lowlands of Missouri, we would never hear of. They would never produce anything even if they had been spread in large numbers. I reason again by analogy according to the history of epidemics of

anthrax where we know that large quantities have been spread over large districts and you never hear of them again. They must have lost their virulence or the number of spores is not sufficient. The individual germ will not produce infection.

4742 It is possible that one of the spores that is carried from the tanneries of Chicago to the proper food media in one of the southeastern counties of Missouri might produce a culture of anthrax germs and produce disease.

4743 It is possible that if it was transplanted to the food and that the food was a proper media at the proper temperature to bring about a multiplication of the germs that it will produce disease but it is not probable and it is not reasonable to believe. It is possible, if I take a spore from a tannery in Chicago, carry it to southeast Missouri to a food preparation and reduce that food preparation to the proper temperature, that I would bring about a multiplication of the germs and if that spore was alive and active and produced a large number of spores upon that media, that it would produce an infection of the disease.

4744 That is possible under the usual conditions of infection but not as probable as in the case of the typhoid bacillus.

Q. You say it is possible. I want to know if as a bacteriologist you do not consider it reasonable on the theory of indirect infection?

A. It is even reasonable under the conditions which usually govern direct infection, that is, first, that the germ is present; second, that it be virulent; third, it is necessary that it finds the proper temperature for its rapid multiplication, and fourth, that the animal infected shall have the necessary reduced resistant forces, and fifth, it is necessary that the animal receive a sufficient number of these germs to produce infection.

ADOLPH GEHRMANN, examined in chief by Judge Springer:

I reside in Chicago and am a physician and bacteriologist. From 1893 I was connected with the Chicago Department of

Health in the capacity of bacteriologist and microscopist for the Milk Department during 1893 and from January, 1894, until June, 1902, as director of the laboratory and bacteriologist of the department. Have taught bacteriology and hygiene in the College of Physicians and Surgeons, which is the medical department of the University of Illinois in Chicago. My connection there began in the spring of 1892 and continues up to the present time. I am now Professor of Hygiene in the Dearborn Medical College at Chicago and am Professor of Bacteriology in the Harvey Medical College in Chicago.

4746 I have all of these connections now. I have been teaching bacteriology for eleven years and hygiene for about eight years. Part of my daily work has been giving special attention to the causes of disease in the human race. In connection with the Health Department of Chicago my employment was the conduct of the laboratory for chemical and bacterial examinations particularly as a bacteriologist.

JUDGE SPRINGER: Q. Where were the samples of water obtained, of which you made bacterial examinations?

A. The laboratory received samples from a number of different places, that is—we were continuously making examinations of water samples from the city water supply. The samples of water were from places where ice was obtained, connected with farms from which milk was supplied from time to time, and for a period, samples of water from the Illinois and Michigan canal, the Illinois and Des Plaines rivers, and tributaries and the Mississippi and Missouri rivers.

4747 During the year 1893, a weekly examination of the water was made from Lake Michigan, from the four tunnels in use and the water supply as delivered in the laboratory, making five samples per week in 1893. These samples were taken at the shore end of the tunnels except the one which was taken in the laboratory which was taken from the tap of the laboratory. From the beginning of 1894 on as long as I was connected with the work the samples were taken daily for every working day. Later some samples were taken from added territory.

(Witness gives names of persons who made chemical analyses of these samples while he was director of the Chicago laboratory.)

4748 The examinations daily were recorded in series and arranged by months. The work each month was tabulated together, averages were drawn, and with the reports that were published from the department a large number of the records for the months were published in detail. They were not all published up to date. These monthly records were published in a number of the reports but they have not all been published up to date, there are one or two years left out. The object of such work was to learn as to the conditions that could be ascertained from bacterial and chemical examinations of the water, as to its quality. These records which were published are in the reports published by the Board of Health of the City of Chicago.

4749 I left the service of the Health Department in June of 1902. I do not hold any official position at this time with the city, state or national government. In the early months of 1899, I was instructed by the Commissioner of Health of the City of Chicago to arrange for the examination of samples from the Illinois and Michigan canal, the Des Plaines river, the Illinois river and its tributaries, and the Mississippi and Missouri rivers, and attended a number of conferences with Professors Palmer and Burrill of the University of Illinois and Professor Jordan of the University of Chicago. The object of these conferences was for the purpose of laying out a plan for the collection of samples and the chemical and bacterial examination of the same at points as before stated, and to arrange for the details of such an investigation. These conferences were to settle first, the localities in which the samples would be collected; second, all matters relating to the exact points in the rivers from which samples would be taken, and the selection of the collectors to be left to the mutual agreement of Professors Jordan and Palmer.

4750 The arrangements for the transportation of the samples and the equipment of the collectors with outfits to be con-

ducted by the Health Department laboratory. It was decided as to the outfits to be used by the collectors.

Q. What did that embrace?

A. That embraced the cases in which the bottles would be shipped, the bottles themselves, the necessary labels, tags and matters of that kind. It was also agreed as to a summary of procedures as to the methods to be used in making the examinations. Three laboratories were engaged in the investigation, the laboratory of the University of Illinois, the laboratory of the University of Chicago and the Health Department of the city of Chicago. At the Chicago laboratory under my charge a chemical and bacteriological examination was made of the samples.

4751 The chemical examination was conducted by D. B. Bisbee and the bacteriological examinations were conducted by myself. It was understood at that time that similar analyses and examinations were to be made at the other two places that I mentioned.

4752 During April and the early part of May, 1899, I purchased the required number of outfits and prepared them for the collectors to use in making their collections. I sent a letter to each collector, copy of which will be found on 4752 of record.

4753 On May 31, 1899, letter was sent to each of the collectors in regard to packing the small bottles in cans, etc. Professors Palmer and Jordan selected the exact point in these various waters at which samples were to be taken and employed the persons who were to take the samples.

4754 I saw several of these collectors engaged in their work along the river. I was at Bridgeport a number of times and at Lockport and Joliet. (Witness states points at which samples were taken in the canal, Kankakee river, Illinois river, Fox river, Big Vermilion, Little Vermilion, Sangamon river, Mississippi river, Missouri river, etc. Witness gives names of collectors at the different points at which samples were taken.)

4757 The outfits furnished these collectors with which to collect samples were accompanied by a slip on which was recorded the number of sample, the date and time of collection, place of collection, temperature, etc. On the back of this slip were printed specific instructions for the collection of samples. (See page 4758.) Samples were all received in good condition in Chicago.

4759 Mr. Bisbee took his large bottles for chemical analyses and delivered the small bottles for bacteriological examination to me and I proceeded with my examination of the samples. Mr. Bisbee made entries on the cards as to the heighth of the water and the temperature, etc., as to all the samples. I made an examination for the numbers of bacteria of all kinds present in the samples by making Petre plate cultures on agar culture medium and counting the number of colonies developed, estimating then the number of bacteria present per cubic centimeter of water. Beyond this, an examination for bacteria of the colon-typhoid group was made. Preliminary cultivation of the water sample in glucose broth and separation of the bacteria therein present, with isolation of the colonies, and studied the specific characteristics presented by the cultures obtained from these colonies. I recorded the results of the examinations on record sheets.

4760 In the tables prepared by me I designated the presence of the bacilli coli communis by a plus sign. Where there is no designation at all, for some reason or other the examination was not completed or fully carried out. Where they are not found the record was made by indicating the minus sign.

Q. Professor, I hand you certain tables numbered from 159 to 196 inclusive, entitled, "Streams Examinations, Sanitary District of Chicago, Sanitary Water Analyses, Parts per Million; Source of Water," indicating at each place in that table where the source was, and designated as a report of Adolph Gehrmann and D. B. Bisbee, Municipal Laboratory, Chicago, Illinois. Will you please examine these tables and state whether or not these are the tables that were prepared by you

and Mr. Bisbee, as chemist in the city laboratory of Chi-
4761 cago, at the times indicated on each of these tables, as the results of chemical analyses and bacteriological examinations of the samples of water taken at various places during the time indicated, in the waters indicated by you in your examination up to this time?

A. These tables that I present are the tables that are prepared in connection with Mr. Bisbee—the record of work on the samples that we received from the collectors at the points as stated before. Mr. Bisbee and myself worked together on these tables. (Witness explains meaning of marks and forms on tables.) (Witness is asked to read each of the tables to which his attention has been called, beginning with No. 159 and ending with No. 196, to which objection was made by Mr. Jeffries. For objection and argument made thereon by Mr. Todd and Judge Springer, see pages 4764-5-6-7-8.) Tables read in evidence beginning with page 4769 and ending on page 4807, said tables showing results of bacteriological and chemical examination of samples of water at the following named points, the page on which each table will be found, being placed after the point indicated:


| | Source of Water. | Point where Sample was taken. | Record Page. |
|---|---|---|---|
| Table 159 | Ill. & Mich. canal | Bridgeport | 4770 |
| 160 | Ill. & Mich. canal | Lockport | 4771 |
| 161 | Des Plaines river | Lockport | 4772 |
| 162 | Des Plaines river | Joliet, north of Jackson st | 4773 |
| 163 | Des Plaines river | Joliet, south of town | 4774 |
| 164 | Kankakee river | Wilmington | 4775 |
| 165 | Illinois river | Morris | 4776 |
| 166 | Fox river | Ottawa | 4777 |
| 167 | Illinois river | Ottawa | 4778 |
| 168 | Big Vermilion river | La Salle | 4779 |
| 169 | Ill. & Mich. canal | La Salle | 4780 |
| 170 | Illinois river | La Salle | 4781 |
| 171 | Illinois river | Henry | 4782 |
| 172 | Illinois river | Averyville | 4783 |

| Source of Water. | Point where Sample was taken. | Record Page. |
|---|---|---|
| 173 Illinois river | Wesley City | 4784 |
| 174 Illinois river | Pekin | 4785 |
| 175 Illinois river | Havana | 4786 |
| 176 Sangamon river | Chandlerville | 4787 |
| 177 Illinois river | Beardstown | 4788 |
| 178 Illinois river | Kampsville | 4789 |
| 179 Illinois river | Grafton | 4790 |
| 180 Mississippi river | Grafton | 4791 |
| 181 Mississippi river | Alton, 100 ft, from Illinois shore | 4792 |
| 182 Mississippi river | Alton, ¼ distance from Illinois shore | 4793 |
| 183 Mississippi river | Alton, midstream | 4794 |
| 184 Mississippi river | Alton, ¼ distance from Missouri shore | 4795 |
| 185 Mississippi river | Alton, 100 ft. from Missouri shore | 4796 |
| 186 Mississippi river | 400 yds. from Ill. shore at Chain of Rocks, Pumping Station, St. Louis Waterworks | 4797 |
| 187 Mississippi river | Midstream at Chain of Rocks, Pumping Station, St. Louis Waterworks | 4798 |
| 188 Mississippi river | Chain of Rocks, Inlet Tower, St. Louis Waterworks | 4799 |
| 189 Mississippi river | 400 ft. from Mo. shore, at Chain of Rocks | 4800 |
| 190 Missouri river | Ft. Bellefontaine, West Alton, Missouri | 4801 |
| 191 Mississippi river | 100 yds. from Ill shore, Jefferson Barracks, Mo. | 4802 |
| 192 Mississippi river | Jefferson Barracks, East of midstream | 4803 |

| Source of Water. | Point where Sample was taken. | Record Page. |
|---|---|---|
| 193 Mississippi river | ...Jefferson Barracks, mid-stream ..... | 4804 |
| 194 Mississippi river | ...Jefferson Barracks, West of midstream ..... | 4805 |
| 195 Mississippi river | ...Jefferson Barracks, 100 yds. from Mo. shore ... | 4806 |
| 196 Tap water | .....St. Louis, Mo. ..... | 4807 |

4808 PROF. ADOLPH GEHRMANN, resumed the stand for further direct examination by Judge Springer:

The tables read in evidence, beginning with No. 159 and concluding with 196 contain a correct statement of the results of its findings.

4810 In Table No. 159, which shows result of examination of samples from Illinois and Michigan canal at Bridgeport, in the column headed "Number of Bacteria per Cubic Centimeter," the lowest number of bacteria per cubic centimeter was 81,350, on July 17, 1899. The largest count was made from sample collected November 27, 1899, and numbered 8,425,000. I have not made up the averages but believe that it would be somewhere in the hundred thousands column. The corresponding column for Averyville, in Table No. 172, shows the lowest number of bacteria found as 7,350,000 per cubic centimeter and the largest number 50,000 per cubic centimeter.

4811 From an examination of these two tables, and the figures contained therein, I should conclude that in the first place there was a difference of from ten to twenty per cent in the number of bacteria present, it being less for the samples at Averyville than for those at Bridgeport, and in some instances a difference of 100 per cent in favor of the samples at Averyville. I should further conclude that the samples collected at Averyville showed a much greater bacterial purity than those collected at Bridgeport. From an examination of the samples collected from the Illinois and Michigan canal at Lockport and those collected from the Illinois river at Averyville, I should conclude in the first place that there were from ten to twenty

per cent less numbers of bacteria in the Illinois river waters at Averyville and in some instances a difference of 100 per cent in favor of the samples from the Illinois river at Averyville,
4812 and should conclude that the water in the Illinois river at Averyville shows a much greater bacterial purity than the waters of the Illinois and Michigan canal at Lockport. Comparing the results of my examinations of the waters of the Illinois and Michigan canal at Bridgeport, the waters of the Illinois river at Morris and the waters of the Illinois river at Averyville, I should conclude in the first place that the numbers of bacteria present are not materially different in the waters of the Illinois and Michigan canal at Bridgeport, and the Illinois river at Morris, and that the waters of the Illinois river at Averyville contain from ten to twenty per cent of the number found at the other two points and in some instances one per cent of the numbers found at the other two points, more particularly at Bridgeport, and that the bacterial condition of the water represented by these tables, shows that the water of the Illinois river at Averyville is of greater bacterial purity than the water of the Illinois river at Morris, or the waters of the Illinois and Michigan canal at Bridgeport. A comparison of the result of the examination of the samples of the water in the Illinois river at Morris, Illinois, the Illinois river at Henry, Illinois, and the Illinois river at Averyville, shows from the numbers of bacteria present, that there is not a material difference between samples collected at Henry and Averyville, except in two instances—August 8th and September 30th, when they were much higher in the Illinois river at Henry. The bacterial counts at these two points are ten to twenty per
4813 cent of those as found at Morris, and show that the water at Henry and at Averyville is of greater bacterial purity than the water of the Illinois river at Morris. The bacterial counts of the waters of the Kankakee river at Wilmington, Illinois and of the Illinois river at Averyville show only slight differences. In some instances they are in favor of the Illinois river and other instances they are in favor of the Kankakee

river. The samples are taken about the same time or near the same time. From a bacterial examination or standpoint I should conclude that there was no material difference in these two waters as to their bacterial purity.

JUDGE SPRINGER: Q. Assuming, Professor, that the Kankakee river above the mouth of the Des Plaines river is merely an upper portion of the Illinois river, differing only in name, from the lower reaches, and assuming that the condition of the water contained in the Kankakee river before its confluence with the Des Plaines river to be as stated in your testimony heretofore, what is your opinion as a bacteriologist, from an examination of the two tables to which your attention has been called, as to whether or not the Illinois river at Averyville has reached a condition bacterially substantially the same as that which it had before the waters of the Des Plaines river and the Chicago drainage canal and the Illinois and Michigan canal were emptied into it?

4814 A. From an examination of the bacterial counts as made of the samples of water from the Kankakee river at Wilmington, and from the Illinois river at Averyville, I should conclude that the examination showed very much the same conditions as regards bacterial purity, the numbers in the majority of instances being not very different.

Q. Then if we assume that there is such a thing in the Illinois river as a zone of bacterial purification where in your opinion, as a bacteriologist, is this zone to be found in the Illinois river?

4815 In reply to this question I can say that from the examination of the samples and the number of bacteria found, that there is a point at about Averyville where the condition as to the number of bacteria exists about equal to that of the tributaries of the river, and that the waters here show the least numbers of bacteria in the course of the river to the point at which they increase next below. I should therefore say that a degree of purification had taken place at about the location of Averyville in the river. My opinion would be from the bacteri-

al count that there was no particular difference in the bacterial purity of the waters in the Kankakee river and at Averyville and nothing that would indicate to us to what amount pollution had been applied between these points or near those points. The results of the examinations of the Illinois river water at Wesley City, and at Pekin showed very much the same condition. There is a wide variation between the counts made at different times, some being as high as two or three million, and others as low as 10,000.

4816 In comparison, the examination of the waters of the Illinois river at Averyville shows in general a much smaller number of bacteria present, not in any instance having been over tens of thousands, and would indicate to me that the water of the Illinois river at Averyville is of greater bacterial purity than the water of the Illinois river at Wesley City or at Pekin. From the difference in these results which is apparent, I attribute the increased bacterial count at Wesley City and Pekin, as compared with that at Averyville, to increased pollution of the river. I have seen that increased pollution coming from the city of Peoria and in that neighborhood. The results of the examination of the Illinois river water at Wesley City and Pekin as compared with those at Grafton, in the Illinois river, show that at Grafton there are from ten to twenty per cent of the bacteria present as shown in the samples from Wesley City and Pekin, and in some instances one per cent of the bacteria that are present at Pekin and Wesley City. I should conclude from this that the waters of the Illinois river

4817 at Grafton show a much greater bacterial purity than those at Wesley City and at Pekin.

Q. If you compared the waters of the Illinois river as disclosed by table 179 at Grafton, with the waters of the Illinois river at Averyville, as disclosed in table 172, what conclusion do you draw so far as these counts are concerned, as to the relative bacterial purity or impurity of the water?

A. I should conclude that the bacterial purity of the water or its condition was about the same. I should conclude from the

bacterial count made on samples of the water of the Illinois river at Wesley City, and Pekin and Grafton, that as far as the bacterial purity is concerned, the river had changed to the condition that we find it in from examination of the samples taken at Averyville, above the City of Peoria.

4818 The results of the bacterial counts of samples taken from the waters of the Illinois river at Grafton and the Mississippi river at Grafton, as shown by tables 179 and 180, show no material difference and I should conclude from this that the bacterial condition of the two rivers is approximately the same from the numbers of bacteria present. The results of the bacterial counts made on the Illinois river at Grafton, and the Missouri river water from Fort Bellefontaine, show that there is no great difference as to the numbers of bacteria from these two points. I should therefore conclude that the bacterial purity or impurity of the two streams is about the same.

4819 Bacterial counts made of the samples of water taken from the Mississippi above the station at the Chain of Rocks, the pumping station of the St. Louis waterworks, all show practically the same bacterial counts, and I should conclude that the bacterial purity or impurity of the water at this point is about the same. There is no material difference in the bacterial counts from samples taken from the Mississippi river 400 yards from the Illinois shore at the Chain of Rocks as shown by table 186 and samples taken at the same place 400 feet from the Missouri shore as shown by table 189. Examination of the result of samples of Mississippi river water taken at the Chain of Rocks, as shown in table 188, compared with the examination of samples of the Mississippi river water taken at Jefferson Barracks, 100 yards from the Missouri shore, shown in table 195, show no material differences as to the number of bacteria present, and I should conclude that the waters at these particular points show approximately the same bacterial purity or impurity.

4820 In the examinations which I made of the waters of the Illinois and Michigan canal and the Illinois river I made

n examination for the colon bacillus and the typhoid bacillus. I did not make any examinations to determine the presence of ny other pathogenic germs. The results of my examinations or the coli communis are correctly stated in the tables which I ave read in evidence. I did not discover any typhoid bacilli n any of these examinations. I cannot say that I found bacillus rodigiosus in waters. I can say, however, that I have found it during the examination of waters. My opinion is that it was an accidental entrance upon the culture plate, caused in some way through the making of the plates, the preparation of the plates, that it arrived on the plates as a contamination approximately. I cannot say positively that such ascertainment or discovery indicated that there were in any of these waters in the vicinity of Chicago, the bacillus prodigiosus. My tests in-
4821 dicated to me that the bacillus prodigiosus is usually present in this vicinity and can be found by exposing material suitable for it to grow, in various places. If there had been large numbers of any particular kind of pathogenic germ I would have found them. Examinations for bacterial counts will give organisms that will grow under the conditions in which the colonies are made, and some bacteria of course will not be developed. We will have to admit that they are lost in the examination. If certain other varieties are present in large enough numbers, they will appear in the examination as a definite part of the examination so that in reply to this question I cannot say that we would have positively isolated the other bacteria present.

4823 In the hospitals with which I am acquainted in Chicago, efforts are made to prevent the spread of infectious diseases in some cases by special rules and special rooms being set apart. In regard to typhoid cases the discharges are disinfected. I can only state positively as to the method of disinfecting where I had something to do with it. It was to place a quantity of one to one thousand of bichloride solution in the vessels in which the discharges were passed, and they were allowed to stand several hours before they were emptied into the

drains and carried into the sewers. That would kill any pathogenic germs that might have been discharged from the patients.

4824 The Health Department issued a circular regarding the care and disinfection of typhoid. (Witness reads instructions in regard to the destruction of the discharges of typhoid fever patients.) In the hospitals where I visited and in my own practice as a physician, as far as I know, these rules were enforced, although I do not believe that this particular disinfectant was used in all cases—its equivalent or something else was used.

4825 R. J. BEDFORD, examined in chief by Mr. Todd:

I live in Dahinda, Knox County, Illinois. Was employed by Prof. Long of the Northwestern University to collect water from the Upper Spoon river. (States where samples were taken, method pursued, etc.)

4827 COMTE MAX Le COUPPEY De La FORREST, examined in chief by Judge Springer:

(See record 4827 for reasons why witness was not asked concerning conditions in the United States.)

4828 My official residence is Paris, France. My title, Secretary of the Commission d'Etudes des Eaux, Paris, France, that is, Secretary of the Commission of studies of water—the study of the sewer waters and water supply for the city of Paris and the metropolitan district of Paris, what we call the Department of the Seine, in France. I am also Secretary of the Society of Hygiene of France, but that is private business—not official business. During the great Exposition in 1900 I was one of the Secretaries of the International Congress of Hygiene in Paris. I am also a sanitary engineer. The city of Paris began the construction of what is known as the irrigation system in 1868. Experiments were made before—from 1866 to 1868 in Clichy, near Paris, for the purification of sewers and

4829 irrigation, and after these experiments it showed that the sewage could readily be purified with irrigation so the city of Paris began, after these experiments were closed, in

1868, to irrigate the fields. In the beginning it was a very small area, it was only fifteen acres that was in operation in 1869, in the place known as Gennevillier, but the areas were not increased immediately, because we had a great war between Germany and France and it was not possible at this time to work, but in 1872, we began to increase this area and every year it would be increased, and now, in 1889 the area of Gennevillier was 1900 acres instead of fifteen acres as in the beginning. The system is very good. The rent of the land before the irrigation was about 45 francs or $9 per acre and after the irrigation the land—the same land, would rent for 200 francs instead of 45, or $40 instead of $9 in the beginning. Soon there was no more room in Gennevillier for further irrigation, so we had to go farther away to a place where the soil was good for irrigation. We went afterwards to Acheres. In the field of Acheres in 1879 we put in operation a superficial area of 2,600 acres. The population of Paris increased, and before that we had very many private cess-pools and we built great sewers and obliged all the houses to be connected with the sewers, and so we must always increase the area of the irrigation field. After Acheres, we built an irrigation field at Mery, of 3,000 acres. This was put in operation in 1898 and after that we built the field at Triel, of 1,800 acres, so the amount now of our irrigation fields is 9,300 acres.

Q. At this time?

A. Yes, sir, now. Our houses are connected with the sewer system in Paris. There are in Paris 80,000 houses, or there were on the 1st of April, 1903. 35,000 of these houses were connected directly with the sewer system. About 25,000 houses have filter cess-pools. The urine and liquids of these filter cess-pools go directly into the sewers, and the solids are afterwards emptied into the Seine, in many places near Paris. So we have in Paris perhaps 60,000 houses which were connected directly or indirectly with the sewer system. The population of Paris is now 2,750,000 inhabitants. Of this the residences of six-eights were connected with the sewer system, so it is about 2,100,000 of the inhabitants that are directly or indirectly connected with the

sewer system. The method of irrigation is not everywhere the same. In Gennevillier, there are little garden farmers who have only a little garden in which to grow vegetables or fruit, and these people can take as much sewage water as they will and when they will. A comparison since twenty years has
4830 shown that these people take always an average of the same amount of water every year.

Q. Sewage water?

A. Yes, sewage water; always the same average every year. They average over 40,000 cubic meters every year per hectare. I will reduce that to gallons. That is 6,500,000 gallons per acre per year, but for the other fields, for Acheres, Mery and Triel all the land, all the country is the property of the city of Paris, and this land is rented to the great farmers, who give some money to the city of Paris for it, and the people are obliged to take every year the same amount of sewage as before. It is a law, which allowed the building of this irrigation field near Paris; the farmers are obliged to take this amount of sewage and to be sure that the people do that, we have many employes of the city of Paris who every day open the gate to the sewer to give the required amount of sewage to the farmers, and we have foremen and engineers to oversee the employes. I think upon the irrigation question that is all that I can say now.

Q. How is the water that was brought onto the land through the irrigation pipes taken away from the land again and returned to the river?

A. It is not the same everywhere. The field of Gennevillier, the field of Archeres and of Triel are near the Seine river, and the field of Mery is near one affluent of the Seine river, near the river Oise, which empties afterwards into the Seine river. We have drained a great portion of the irrigation field with tile drain and this title drain empties into little creeks that afterwards empty into the river Seine or the river Oise. All the effluent of the sewage will be discharged into the river Seine after purification through the soil, and this purification is good. In Acheres, Mery and Triel, where the land is the property of the

city, the city of Paris has built little gardens, because cities desire always that her works are pretty for the visitors and in these gardens are lakes. These lakes are supplied only with
4831 the effluent water from the irrigation field, and in these lakes live many fish, and at the point where the main drain comes into or empties into the lakes there are springs, but the springs are all of the effluent water. And all of the workmen who live on these different farms—there are perhaps 200 or 400 hundred of these workmen living in this country, they drink only the water of the effluents, and we have a medical survey of these men. All the physicians of the country are connected with the city of Paris and must give weekly reports upon the sanitary conditions of all these men, of all these workmen, and since these different irrigation fields are in operation we have had no typhoid fever or cholera or dysentery, or the diseases which come from water. Those who use the water from the irrigation fields, or the effluents, have not had any of these diseases. I have drank the water myself very often and many times, foreign people who come to see our irrigation field, whom I, as engineer of the city of Paris, would take to the irrigation field, would drink and I drank always the water. There are three reasons which caused the government of paris to adopt this irrigation system. The first reason you might say is only a pleasure reason, the other was a sanitary reason and the third, industrial. Above Paris are little cities and residence towns, to which came in the summer time many people of Paris. There are perhaps three or four hundred thousand people who come from Paris during the summer to live, near Paris, 20 or 30 miles below Paris, that is below the city. All of these residences are built on the banks of the river Seine are very pretty, many trees and little hills; it is very pretty and very agreeable, but when the city of Paris began to discharge its sewage into the Seine, there was a great smell, the water was very dirty; it was no more possible to bathe in the water and every year the condition got worse and worse and that began in 1860 and from 1860 to 1870 that was always worse and worse. That is the pleasure reason

if I can say so. And the second reason is the sanitary reason, and that is that in summer when the river Seine is low the people who live near the Seine had in time a little fever, not typhoid but malaria or something like that. Not quite malaria, but a little fever, intermittent fever at the point where the river Seine was low and where the river had many branches. And the third reason is an industrial reason if you can say so. There are a great deal of people who live below Paris between Paris and perhaps sixty miles below engaged in the fishing industry and all of the fish died because there was too much sewage in the water and every year the condition of the fish became worse and worse because the amount of the sewage that was discharged into the river was in summer diluted in a very small amount of water. The dilution of the sewage in the Seine was only at this time one-fifteenth or one-eighteenth. That means one part of sewage was diluted in fifteen times that many parts of Seine water or eighteen parts of Seine water.

Q. How far down the river did this pollution extend at that time during that period?

A. Perhaps 35 miles below Paris in the summer time. I have here the different chemical analyses of the river Seine, above Paris, in Paris, below Paris, and at many points below Paris from 5 miles to 100 miles below Paris. That was before the irrigation was begun. One of the analyses is for 1847 and the other 1869, when we were ready to begin the irrigation in the field of Gennevillier and I also have here the organic matter and the total nitrogen in the water. You can see that where the main sewer emptied at this time into the river Seine, it was 25 parts of total nitrogen in the water per 100,000 parts of the river Seine and 42 miles below, near the city of Maneese, it was only 1.4 instead of 25 parts.

4833 I have also the figure for the organic nitrogen at the same point where the main sewer emptied into the river Seine. It was 7.2 parts of organic nitrogen per 100,000 parts of the river Seine and near the city of Meulan 40 miles below Paris, it was only .4 of a part of organic nitrogen per 100,000

parts of water of the river Seine. So we can see that at this time the river Seine had a self-purification after 45 miles, at this time in 1869. At that time perhaps only 800,000 people deposited their sewage into that river. At this time the city of Paris has 2,750,000 inhabitants. The people of Paris do not now discharge the sewage into the sewers and into the river Seine. They discharge it into the irrigation fields, that is, six-eighths of the inhabitants do and the other two-eighths sell their sewage to a company who make fertilizer of it. The suburbs below and above Paris also discharge their sewage directly into the Seine and that was a population of about 1,100,000 in 1899. The two-eighths of the sewage of the city of Paris that is not carried off into the irrigation fields, those people fix cess pools in their houses and a company will empty these cess pools once or twice a year and will make fertilizer with all the matter that was in the cess pools.

4834 These people must pay something to the company for the removal. They pay per cubic meter. I think in some parts of France it is two francs per cubic meter. I do not know the general price. This irrigation plant has cost the city of Paris, up to the present time, as follows:

Gennevillier cost, 5,200,000 francs.

Acheres cost, 10,500,000 francs.

Mery cost, 10,800,000 francs.

Triel cost, 15,000,000 francs.

Buildings for housing of machinery and general expenses 5,000,000 francs. I am sorry but I have not here the cost of maintenance. I have only the cost of the elevation of the sewage, to put the sewage into the irrigation field, and this cost is something high, because we must elevate the sewage very much. The pumping of the sewage comes very high. This cost in 1901 was 2,967,500 francs, or $593,000. That is the cost for the pumping. I haven't the other figures here. The other cost is very high because at Acheres, Mery and Triel we have a great many employes who must open every day the gates of the sewers. We

have perhaps 200 of these men and I do not know how much these people cost.

4835 The employes are what we name in French skilled workmen. They are well informed and do not work alone. There are all the time foremen and many superintendents and three sanitary engineers above the superintendents. For the purpose of ascertaining the character and condition of the water above and below the city we make chemical and bacteriological experiments of the water in the Seine and continually we make analyses and examinations of the drainage of the different irrigation fields. Below Paris we take two samples every week, five miles below Paris, ten miles and fifteen miles below Paris, two times every week, and the effluents of the different drains in the different irrigation fields are also examined for bacteria and for chemical compositions, every week, one or two times or three times, not always the same. The river Seine at all times is polluted by many cities above Paris so that the water is not drinkable in Paris, but below Paris after it has emptied into the river Seine the sewage perhaps of 1,000,000 or 1,200,000 inhabitants, the condition of the river Seine is very much worse than above Paris.

4836 In summer immediately above Paris especially, fish cannot live in the water of the river Seine. In the summer time the volume of the water in the Seine below Paris is 126,000 cubic feet per minute in the lowest stages. In the ordinary months, it is 190,000 cubic feet per minute. I have said that in 1869 when 800,000 people discharged their sewage in the river Seine, the purification of the Seine was perhaps—the zone of purification was perhaps 45 miles below Paris, but now we have perhaps 1,200,000 people who discharge their sewage into the river Seine, and the zone is, I think—I am not quite sure— it is perhaps 55 miles below Paris. I have no figures here but I think that it is so, 55 miles. I have the figures in Paris but I have not them here. I am almost sure that it is 55 miles from Paris and I must say that the sewage is diluted now in the proportion of 1 to 20. One part of sewage to 20 parts of the river Seine. We

have in Paris a double water supply and two kinds of pipes. We have drinking water and cleaning water.

4837 We use the river Seine water for everything except drinking purposes and cooking purposes. The drinking water comes from springs which are far away from Paris and is brought there over aqueducts. The shortest is 60 miles long and the greatest is 110 miles and now we are bringing to Paris new springs and the aqueduct will be 200 miles long. We furnish each day 24 gallons of drinking water and 45 gallons of cleaning water per capita. The river Vanne furnishes one-third of the amount of drinking water. Vanne is not a river—there are springs which are in the valley of the river. It is really a spring.

4838 CROSS-EXAMINATION By Mr. Jeffries.

Paris is not quite sure whether it will further extend its sewer fields or whether it will be a sewage field or septic tanks or the aerobic system, because these septic tanks, or the aerobic system do not cost us so much as the irrigation field. Two years ago the chief engineer of the sewers of Paris was sent to England to study the septic tanks and this year I was sent to America to see what the American people are doing for sewage disposal because we must increase our system of sewage in Paris. There are 60,000 houses connected directly or indirectly with the sewerage system and we must build a sewage plant for the 20,000 houses that are not connected. This must be a field irrigation or a septic tank or something else. The object of the authorities of Paris in treating this sewage is to purify the Seine between Paris and 55 miles below Paris where the self-purification of the river is not great enough. It is 250 miles perhaps from Paris to the sea by the river Seine. The city of Paris has two sources of revenue for the sewage. First, each house that connects with the sewage system must pay a tax, and second the irrigation fields are rented to farmers who give a great sum of money, but I think that in all it costs something to the city of Paris, because we must elevate the sewage very much and so we must increase often the tax for the connection

from the houses to the sewer to do that. It cost nothing to the city. On these irrigation fields it is not allowed the farmers to produce all kinds of crops. They won't allow them to grow the crops which people eat raw without cooking, such as raw fruit and salad, and it is no more allowed to make the crops of wheat that will grow very near from the soil, because we have seen that people who will eat the crops that grow very near to the soil, which is covered with the sewage and which has in it the bad bacteria, and the people who eat that, afterwards can be sick. The board of health of Paris first, and afterwards several boards of health of France, prohibited the use of the soil for fruits and crops which grow very near to the soil, that can be eaten without cooking, and since the board of health, two or three years ago, made this prohibition, or regulation, the condition for the farmer is not so good as before, because before that they had very good strawberries and slaw and salad, which they cannot any more have now. I just say that I and my family before the board of health said that, for the last fifteen years, we have never eaten any Paris raw salad because the greatest quantity of salad in Paris came from the irrigation fields, and I say it is very dangerous to eat the salad. Not so now, because now the salad comes no more from the irrigation field but comes from other gardens or fields and does not come any more from the irrigation fields, but before that it was very dangerous to eat the salad from Paris. They can grow potatoes, because you eat cooked potatoes and you will not eat the shell of the potato, it would be dangerous to eat the shell of the raw potato, but nobody ever does that. Before that order the sewage fields were a good revenue. I do not know how much revenue per acre they derived from these sewage fields but the field at Gennevillier does not belong to the city. It belongs to private people. There they have crops like strawberries and salad and asparagus. This kind of crops will give very much more money than other crops, perhaps ten times more. I know that for Gennevillier the rent of the soil is 300 francs per acre and that is six times as much as they get for good soil in France. An effort is now being made

to purify the sewage of 1,200,000 people which is directly emptied into the river Seine and the sewage of perhaps 500,000 people who live near Paris. They are going to do away with the sale of the sewage to private companies and are going to treat it in some way that has not yet been determined upon. After that has been treated it will comprise practically all the population of Paris and its suburbs. The idea in making this investigation being to obtain the most approved and scientific method of treatment, with a view to removing all of the harmful substances from the sewage. This sewage is immediately taken in charge by the farmers night and day. An employe of the city of Paris will open the gates of the sewer, just as the man will say to this man, one day in one part of the field and the other day in the other part, and none of the sewers will remain without being used. They are used immediately. It goes through the sewer and is immediately discharged upon the field.

4842 J. J. STITES, examined in chief by Judge Springer:

Am a physician and live at Pontiac on the Big Vermilion river. Took some samples of water from the river for Dr. Long of the Northwestern University, in November and December, 1899.

4843 (States places where samples were taken and method employed, etc. Testimony of this witness objected to because samples of water were taken from the tributaries of the Illinois river.)

4846 B. F. LONG, examined in chief by Judge Springer:

Am a stationary engineer and reside at Joliet. Took samples of water from the Des Plaines river at Joliet at the instance of Dr. Long, in the summer of 1899 and the summer of 1900. (States where samples were taken, method used and where they were shipped.)

4852 PROF. ADOLPH GEHRMANN, resumed the stand for cross-examination by Mr. Jeffries:

The determination of the number of bacteria present in

water is a small part of the examination of water for purity. It indicates a degree rather than an absolute fact. The kinds of bacteria are more important than numbers and so far as pathogenic bacteria are concerned, the kinds may depend to a degree upon the source of pollution. A cubic centimeter is about one-quarter of a drachm. I do not know how it would compare with an ordinary thimble. I have no experience as to thimbles.

4853 These examinations were made in water known as dilutions. It became necessary, owing to the large number of bacteria present to dilute the water 100 times or a thousand times and then take a portion of this dilution for the plate cultivation, so that in none of the instances was a cubic centimeter taken.

4854 Q. Now, doctor, was this small quantity of water examined sufficient to determine with accuracy the bacterial condition of the whole canal or river from which it came?

A. I might confess that an examination of this kind shows a degree of accuracy that gives results that can be comparable with other results made about the same time or in the same line of work. Such an examination is scientific but it is not like mathematics. I believe each particular sample would be a representative of all the water in the river at the point where taken, for the time and moment that it was collected.

4855 I do not think that the bacterial count in itself will decide as to the sanitary condition of water. The bacterial count is not a statement of quality, it is distinctly a statement of quantity. When I testified that the bacterial purity of water examined by me from the Illinois and Mississippi rivers at Grafton was about the same, I was speaking at the time about the numbers of bacteria present, and the results indicate that as far as the numbers of bacteria and the activity of the bacteria present in the water in these two localities, is approximately the same.

4856 Bacterial purity is not recognized as its sanitary condition, except as far as the general activity of decomposi-

tion that is taking place, is concerned, which has a slight bearing on the question as to purity or impurity.

4858 I examined the water from the Two Mile tunnel and the Four Mile tunnel at the time there was typhoid existing in the 19th ward of Chicago and also before that time and did not discover any typhoid bacilli in such water. I don't believe the typhoid bacilli were there. I am quite certain that that epidemic did not come from the water.

4859 The epidemics that I have any definite knowledge of in Chicago, outside of the one of the past year, 1902, were due to the water. I would say that about one-half of the cases of typhoid fever in Chicago since 1894 under all circumstances come from the water supply, owing to two or three causes. There has been continuously a certain amount of flow of sewage into the lake, especially along the south side, from 35th street, south, so that infectious matter could be carried out to the cribs, and there has been dumping of dredges along shore almost continuously during these years.

4860 I have noted some slight difference in the bacterial count of Lake Michigan water during the time typhoid fever was prevalent in Chicago. In one small increase in typhoid that occurred in 1897 the bacteria were more numerous and the water was worse at that time and there was an increase in typhoid two or three weeks later. That is the only one that I can recall that is very definite. The water of Lake Michigan during all of the years that analyses have been made by me and in my laboratory taken from the various cribs, in respect to bacterial count and bacterial purity are better than the averages which I have obtained from Grafton. I am very certain that upon many occasions the bacteria found in the water of Lake Michigan came from the dredgings that were deposited in the lake, because I had occasion to follow the dredge or follow the water for as much as an entire afternoon, as to its movement in the lake. The dredging referred to is not one of stirring up but it is the emptying of dredgings from the scows into the water and my view is that a portion of the typhoid comes from

these dredgings but not any material proportion of the typhoid. The typhoid that we have, that is, that portion of it that we can attribute to the water, comes from the direct transfer of infectious matter from the sewers to the cribs. I think the dredging is a party to it, but to a less extent.

4861 When I said the counts were better in comparing the bacterial counts in Lake Michigan with those of the Illinois at Grafton I meant that they were lower in the waters of Lake Michigan. The bacterial counts I made were made upon agar plates. We kept them at 18 to 20 centigrade. It was the intention to keep it exact but it ranged from 18 to 20. That would be what is known as moderate room temperature. I have found bacillus prodigiosus in examinations of different kinds. When I really tried to get a culture of bacillus prodigiosus, I took plates where there was decomposed vegetable matter in considerable quantity. For instance in a garden, cabbage field or something of that sort, and I found it there. I believe that it lives wild in the United States.

4862 It is not common in nature. Sometimes it appears in considerable numbers at a given point. As a general thing thing it does not. It is not as prevalent as many other organisms.

4863 The examinations that I have made as to the extent of bacterial contamination in Lake Michigan from the lake front at Chicago show that the degree to which the sewage and shore contamination would extend into the lake varies a great deal, varies rapidly at times, depending upon wind movement and the amount of rainfall as to the flushing of sewers. Some of the recorded examinations show that there is no evidence of any pollution any further out than two miles and again we have evidence of pollution by the presence of excessive numbers of bacteria and colon bacillus ten miles out. The sewage entering Lake Michigan is highly diluted before it enters the intakes of the city waterworks. I have used in my water examinations the so-called guinea pig tests for the purpose of determining the presence of pathogenic germs. This test will not necessarily

show the presence of typhoid bacilli. It might under some circumstances but not as a routine method. I do not believe it would positively in all cases show the absence of it.

4864 I consider that an important test in water examinations. It was not used in my examinations of the water of the Illinois river because the examinations that were made were made in the way they were made on account of a mutual agreement between a number of parties to which I was a part, and the concensus of opinion was to conduct them in that way. That is all I know about it. The difficulties of animal experiments may have a possible bearing on a question of that kind. A pathogenic micro-organism is one that under conditions is able to alter physiological conditions. The alteration of any physiological function has in it at the bottom the disease or pathological condition.

Q. But it may not be an infectious disease germ?

A. Infectious? No, it might be a toxic disease. The saprophytic bacteria is one that is capable of living on dead organic matter. Pathogenic germs may be capable of living on dead material in laboratories and may be what we call facultative, that is, may live either on dead material or as parasites on living material. In the analyses of the water from the Illinois river in 1899, I recorded simply the presence of the colon bacillus and not the numbers.

4866 These examinations by the Chicago Health Department were made under my immediate supervision. I made a great many of the counts and the direct examinations personally. I have supervised the work personally throughout. I had as assistants, Kierueff and Dr. Kilburn.

RE-DIRECT EXAMINATION, by Judge Springer:

As to the effect of taking the 12th and 22d street sewers from the lake and turning them into the Chicago river, on the typhoid death rate in Chicago, I will say that these two sewers were relaid in 1898 and 1899. The work was completed in the fall and winter of 1899 and the drainage of all of the district as far south as 31st street in this city was changed from dis-

charge into the lake to discharge into the river, that is westward. The records of the following year show that 1900 is the best year that the city has had as regards typhoid fever. It is due in part to the removal of this amount of drainage from the lake, because these sewers were in such a position that their discharge would pass more nearly opposite the important intakes. The removal of the intakes further into the lake has reduced the amount of typhoid fever in Chicago because of the greater dilution and greater time required for the sewage matter to reach the intakes. The increase in typhoid in 1902 was mainly a local epidemic in the Nineteenth ward and was due to the overflow of the portion of the basement and a pump well of the Harrison street pumping station during the early summer and also to the presence of open vaults in this ward, as shown by the investigations of the members of Hull House and published in the report of the City Homes Association. In the overflow of this pump well as stated, it was found that a sewer connection had overflowed and was the direct cause of the flooding by sewage from the street sewers. Out of 402 deaths recorded in 1902, 180 were in this immediate neighborhood, that is something over 35 per cent. When I say immediate vicinity, I mean the 19th ward, which has a population probably of 30,000 or 40,000 people. If sewage should pass into the lake at this time or if sewage is now passing into the lake, there is not more typhoid fever in Chicago because the intakes are at such distance from the shore that the dilution of the sewage is so great and the time for the passage to the intakes and back to the population is sufficient to give opportunity for destruction in a considerable portion of the infectious matter.

Q. From your studies of the water supply of Chicago and from your knowledge of what has been done in reference to this supply, will you state what improvements, if any, have been made in the system from time to time?

4869 A. Up to the years 1890 and 1891, the intakes for the obtaining of water were not over two miles from shore, the furthest being two miles. Other intakes were less than a mile

from shore, and up to that time there had been a continuous excess of typhoid fever in the city. In the epidemic of 1890 and 1891, and a portion of 1892, which was due to the special taking of water from the shore intake, the extension of the intakes was completed, and from that time a marked decrease in typhoid was noticeable. In 1899 the work of relaying the sewers at 12th and 22d streets was completed and a further decrease in typhoid resulted. By infectious matter, I mean portions of the structures or tissues or excretions of the individual containing the micro-organisms that will lead to infection.

RE-CROSS EXAMINATION, by Mr. Jeffries:

Undoubtedly if all the sewage of Chicago was turned into Lake Michigan today it would increase the number of typhoid cases in Chicago.

4870 The dilution of typhoid bacteria in the water of Lake Michigan when the average typhoid conditions at Chicago existed must be extremely great because I cannot find the typhoid bacillus in the water and I have made many examinations of the water of Lake Michigan for that purpose.

4871 When I find colon bacilli present in water that I am examining, which water I know has produced typhoid fever among the people using it, I conclude that the presence of the colon is in part significant of the presence of other organisms, but the effect that the water has upon the peo-

4872 ple using it is better index than the simple finding of the colon bacillus. Dilution pure and simple would not remove pathogenic micro-organisms from a lake or running stream. It would aid in their destruction because it would bring about a more rapid dissemination and breaking up of the particles derived from individuals that are sick with the various diseases and in that way would liberate the micro-organisms from the protection of particles, so the destructive effects might be more easily operative in bringing about their ultimate death.

4873 Assuming that a typhoid bacillus was deposited in an ordinary well I would not recommend the use of that water knowing that the bacillus had been deposited there. I do

not believe that there is very much danger from even a few single free typhoid bacilli. I must draw a distinction between infectious matter and free single typhoid bacilli and in a case where I knew positively that one typhoid bacillus had been placed in a certain quantity of water, without knowing anything of the conditions under which that water was to be placed, the amount of organic matter in it, the possibility of the rejuvenation and growth of them—of this single typhoid bacillus, of course I should say that the water was not potable. But under conditions where I knew that there would probably be no multiplication of that typhoid bacillus in the water—no incarnation as it were, of the amount of infection present, I should not myself have any hesitancy in drinking the water, because I do not believe, even though I should swallow that one germ—that it would affect me. I believe that in highly contaminated water, where decomposition and the action of saprophytes is very active, the pathogenic organisms, or disease producing organisms are more quickly destroyed.

4875 D. B. BISBEE, examined in chief by Judge Springer: Live at La Grange, Illinois. Am a chemist. Graduated from the Agricultural College of Iowa and took a post-graduate course afterwards. Made chemistry my specialty right straight through.

4876 For four years, beginning in February, 1896, I was Assistant City Chemist of Chicago and was engaged all that time in water analyses. I am now Chief Chemist of the City of Chicago. I should say that I made analyses, on an average, of seven samples a day six days in the week, for the four years referred to. I also made chemical analyses of a number of ices, milks and other liquids.

4877 I heard parts of Dr. Gehrmann's testimony. The tables to which you call my attention, beginning with 159 and ending with 196, to which Dr. Gehrmann referred, are the tables that were drawn up from my notes—that of Streams Examination work, which I did jointly with Dr. Gehrmann.

4878 I made all the parts of those tables with the exception

of the notes under the headings, "Heighth of Water," "Temperature of Water," "Temperature of Air," "Presence or Absence of Coli," and the number of bacteria per cubic centimeter." (Witness states how samples were received and the method employed in determining the qualities enumerated in the tables, of turbidity, sediment, color and odor, residue on evaporation, chlorine, oxygen consumption, total dissolved and suspended matter, etc.)

4889 CROSS-EXAMINATION, by Mr. Jeffries:

There was no test for sediment. It was just simply the relative amounts that I judged present. It appears on the bottom of the tables.

4890 It was by ocular observation, that is all. If the sediment had been as transparent as the water I would not have been able to detect it. If there had been living organisms existing in the water capable of motility I would not have been able to detect them with the naked eye. As to the turbidity, I judged that; it was simply an estimation; it was my judgment. The question of turbidity does not in itself determine the presence or absence of living organisms that do or do not produce disease.

4891 It has nothing to do with the question of the presence or absence of micro-organisms. Samples of water may contain large quantities of various chemical substances which would be considered by chemists as rendering the water unpotable and at the same time would not contain a single disease producing organism.

4892 It would not be a living mass of organisms of any kind unless there was at least a certain amount of organic matter for them to live upon and you could detect that. The organic matter may be present with the disease producing germs absent. Unless the organic matter was there the disease producing germs could be present but they could not live.

Q. So then, the idea is, the more organic matter, of whatsoever character, contained in any water, the more dangerous it is for domestic purposes, is that it?

A. The more apt we are to mark it suspicious, or call it unpotable water.

4894 In November the amount of suspended matter found at Grafton in 1899 was five or six times higher than what was found in July. The sample examined on the 7th of July and the 13th of July was 7 parts per million of suspended matter and on the 20th of July was 16 parts per million; July 27th, 18 parts per million; November 3, 94 parts per million; November 10th, 27 parts per million; November 16th, 48 parts

4895 per million; November 23, 85 parts per million, so that there was a greater amount of suspended matter during the month of November than there was during the month of July. (States how the determinations of residue on evaporation were made. As to the effect of delay in shipment of samples prior to their examination by witness, see pages 4899, 4900, 4901.)

4903 ARTHUR W. PALMER, examined in chief by Judge Springer:

I reside at Champaign, Illinois. Am Professor of Chemistry in the University of Illinois. Have held that position fourteen years. Was educated in the public schools of Illinois; at the University of Illinois; at Harvard; at Berlin and Goettingen in Germany. (States qualifications.) Have been engaged in making chemical analyses about 22 years as a student and investigator. I had conferences with Prof. Jordan of the University of Chicago with reference to making certain examinations and analyses of the Illinois and Michigan canal, Sanitary canal, Des Plaines, Illinois and other rivers, in March, 1899.

4905 The conference in March, 1899, included a number of other individuals besides Professor Jordan and myself and at that conference it was decided that samples of water should be taken at various points along the Illinois river, the Mississippi river, the Missouri river at one point, and from the Illinois and Michigan canal. Also from some of the tributary streams of the Illinois, and that samples should be taken from

each point selected, once a week; that the number of samples taken at each point simultaneously should be sufficient to send one set of said samples to Prof. Jordan at the University of Chicago; one set to Dr. Gehrman, at the municipal laboratory, Chicago, and one set to me at the University of Illinois. Professor Jordan and I jointly selected the persons who were to take the samples of water and the places at which they were to be taken. We went to different points along the different streams mentioned just before—visited them, noted local conditions, pointed out the spot where a sample which should be most representative of the conditions in the river in that vicinity, could be obtained. We selected men to make the collections by reason of their availability and their apparent fitness for doing the work. (Witness states points at which samples were taken and the reasons why such points were selected, also names of the persons who took the samples at the points indicated.)

4918 The relative flow of the Illinois and Mississippi rivers at Grafton in the year 1899, taking the mean for the year through was about five times, or a little more than five times as much in the Mississippi as in the Illinois. Measurements were made by U. S. engineers about the year 1882 at the mouth of the Illinois and at Hanibal in the Mississippi river.

4919 Measurements of the flow in the Illinois river have been made at Kampsville where the flow as measured constitutes ordinarily practically all the flow of the Illinois river at Grafton, and so indicates the volume of water discharged into the Mississippi at the mouth at Grafton. For 1900 the flow of the Illinois amounted to about 22.6 parts as compared with 77.4 for the upper Mississippi. These determinations being made from the determinations of the proportions of chlorine contained in the Illinois river water, and a comparison with the proportions of chlorine contained in the upper Mississippi river water and in the water of the Mississippi river below the mouth of the Illinois, where partially mixing of the two streams occurred. (It is important to read testimony of this witness as to reasons samples were taken at the points selected. Witness states what

instructions collectors were given and method pursued in collecting samples and shipping them to laboratories. After their receipt the analyses were begun immediately, particularly the determination of such constituents as are susceptible to change readily. Witness states method of determining the color, odor, total solids, loss on ignition, presence of chlorine, oxygen consumed, nitrogen as free or solid ammonia, etc.)

4928 Nesslerization is the determination of free ammonia in solution by means of the so-called Nessler re-agent. (States method by which this was done.)

4936 The results of these analyses about which I have been testifying were set forth in certain tables which were numbered from 1 to 80. I identify the tables which you have just placed in my hands, as the ones to which I but a moment ago referred as incorporating the results of the various analyses of the samples of river waters which are the subject of the present investigation. These tables contain a correct statement of the determinations which are indicated in the tables respectively.

MR. JEFFRIES: I object to the reading of the tables because no proper foundation has been laid for their introduction.

4937 Complainant further objects for the reason that according to the explanation given by this witness and all other witnesses who have been produced by defendants, they are unable to give any connection between the analyses of the samples of water taken from the Illinois river, the drainage canal and the Chicago river, and the sanitary condition of the water in the river. Complainant objects for the further reason that this witness has not qualified as a sanitarian or a pathologist, and for the further reason that there is nothing in the tables which shows the presence or absence of disease-producing organisms, and for the further reason that defendants have proved that this is beyond the power of the science of chemistry to determine, the sanitary condition of water for domestic and drinking purposes. Complainant objects for the further reason that the

samples of water were not taken with reference to all conditions of the river so far as temperature and the seasons of the year are concerned, and the manner of taking was not such that the results of the analyses based thereon are comparable with each other, or that the results are in any way comparable with the conditions actually existing in the river at any time and at all times.

(Motion by Judge Springer to strike out objection.)

4938 These tables were read in evidence and are numbered from 1 to 80. They will be found on pages 4939 to 5026 inclusive, The source from which the sample of water was taken is indicated and the page on which the table will be found, follows such indication. The samples were taken from May 23, to Dec. 27, 1899.

| Table. | Source of Water. | Place of taking sample. | Record Page. |
|---|---|---|---|
| 1 | Ill. & Mich. canal | Bridgeport | 4939 |
| 2 | Ill. & Mich. canal | Lockport | 4940 |
| 3 | Des Plaines river | Lockport | 4941 |
| 4 | Des Plaines river | Joliet, nor. of Jackson st. | 4942 |
| 5 | Des Plaines river | Joliet, south of town | 4943 |
| 6 | Kankakee river | Wilmington | 4944 |
| 7 | Illinois river | Morris | 4945 |
| 8 | Fox river | Ottawa | 4946 |
| 9 | Illinois river | Ottawa | 4947 |
| 10 | Big Vermillion river | La Salle | 4948 |
| 11 | Ill. & Mich. canal | La Salle | 4949 |
| 12 | Illinois river | La Salle | 4950 |
| 13 | Illinois river | Henry | 4951 |
| 14 | Illinois river | Averyville | 4952 |
| 15 | Illinois river | Wesley City | 4953 |
| 16 | Illinois river | Pekin | 4954 |
| 17 | Illinois river | Havana | 4955 |
| 18 | Sargamon river | Chandlerville | 4956 |
| 19 | Illinois river | Beardstown | 4957 |
| 20 | Illinois river | Kampsville | 4958 |
| 21 | Illinois river | Grafton | 4959 |

| Table. | Source of Water. | Place of taking sample. | Record Page. |
|---|---|---|---|
| 22 | Mississippi river | Grafton | 4960 |
| 23 | Mississippi river | Alton | 4961 |
| 24 | Mississippi river | Alton, ¼ distance from Ill. shore | 4962 |
| 25 | Mississippi river | Alton, midstream | 4963 |
| 26 | Mississippi river | Alton, ¼ distance from Mo. shore | 4964 |
| 27 | Mississippi river | Alton, 100 ft, from Mo. shore | 4965 |
| 28 | Mississippi river | Chain of Rocks Pumping Station, 400 ft, from Ill. shr, St. L. waterworks. | 4966 |
| 29 | Mississippi river | Chain of Rocks, midstream, pumping sta. St. L. waterworks | 4967 |
| 30 | Mississippi river | Chain of Rocks, Inlet Tower, St. L. waterworks.. | 4968 |
| 31 | Mississippi river | 400 ft. from Mo. shore, at Chain of Rocks, Pumping Sta. St. L. W. w'ks. | 4969 |
| 32 | Missouri river | W. Alton, Mo.—Ft. Bellefontaine | 4970 |
| 33 | Mississippi river | Jefferson Barracks, Mo., 100 yds from Ill. shore. | 4971 |
| 34 | Mississippi river | Jefferson Barracks, Mo., east of midstream | 4972 |
| 35 | Mississippi river | Jefferson Barracks, Mo., midstream | 4973 |
| 36 | Mississippi river | Jefferson Barracks, Mo., west of midstream | 4974 |
| 37 | Mississippi river | Jefferson Barracks, Mo., 100 yds. from Mo. shore. | 4975 |
| 38 | Tap water | St. Louis | 4976 |
| 39 | Sanitary Canal | Kedzie Avenue | 4977 |
| 40 | Ill. & Mich. canal | Bridgeport | 4978 |
| 41 | Ill. & Mich. canal | Lockport | 4979 |

| Table. | Source of Water. | Place of taking sample. | Record Page. |
|---|---|---|---|
| 42 | Des Plaines river | Lockport | 4980 |
| 43 | Drainage Canal | Lockport–Bear Trap dam. | 4981 |
| 44 | Des Plaines river | Joliet—North of Jackson street | 4982 |
| 45 | Kankakee river | Wilmington | 4983 |
| 46 | Illinois river | Morris | 4984 |
| 47 | Fox river | Ottawa | 4985 |
| 48 | Illinois river | Ottawa | 4986 |
| 49 | Big Vermillion river | La Salle | 4987 |
| 50 | Illinois river | La Salle | 4988 |
| 51 | Ill. & Mich. canal | La Salle | 4989 |
| 52 | Illinois river | Henry | 4990 |
| 53 | Illinois river | Averyville | 4991 |
| 54 | Illinois river | Wesley City | 4992 |
| 55 | Illinois river | Pekin | 4993 |
| 56 | Illinois river | Havana | 4994 |
| 57 | Sangamon river | Chandlerville | 4995 |
| 58 | Illinois river | Beardstown | 4996 |
| 59 | Illinois river | Kampsville | 4997 |
| 60 | Illinois river | Grafton | 4998-9, 5000-1 |
| 61 | Mississippi river | Grafton | 5002-3-4 |
| 62 | Illinois river | Grafton | 5005 |
| 63 | Mississippi river | Grafton | 5006 |
| 64 | Mississippi river | Grafton | 5007 |
| 65 | Mississippi river | Alton, ¼ distance from Ill. shore | 5008 |
| 66 | Mississippi river | Alton—midstream | 5009 |
| 67 | Mississippi river | Alton, ¼ distance from Mo. shore | 5010 |
| 68 | Mississippi river | Alton, 100 ft. from Mo. shore | 5011 |
| 69 | Mississippi river | 400 ft. from Ill. shore at Chain of Rocks, St. L. waterworks pumping station | 5012-13 |

| Table. | Source of Water. | Place of taking sample. | Record Page. |
|---|---|---|---|
| 70 | Mississippi river | Midstream, at Chain of Rocks, pumping station, St. Louis waterw'ks. | 5014-15 |
| 71 | Mississippi river | Chain of Rocks, Inlet Tower, St. Louis waterworks | 5016-17 |
| 72 | Mississippi river | 400 ft. from Mo. shore, at Chain of Rocks, pumping sta. St. Louis waterworks | 5018-19 |
| 73 | Missouri river | Ft. Bellefontaine, W. Alton, Mo | 5020 |
| 74 | Mississippi river | Jefferson Barracks, Mo., 100 yds. from Ill. shore. | 5021 |
| 75 | Mississippi river | Jefferson Barracks, east of midstream | 5022 |
| 76 | Mississippi river | Jefferson Barracks, midstream | 5023 |
| 77 | Mississippi river | Jefferson Barracks, west of midstream | 5024 |
| 78 | Mississippi river | Jefferson Barracks, 100 yds. from Mo. shore | 5025 |
| 79-80 | Tap water | St. Louis, Mo. | 5026 |

5027 I prepared these tables myself. They are the original tables. My original was in pen and ink and this is a printed sheet. I read the proof sheets after they were set up by the printer and compared them with the papers I had prepared in the first instance and made the necessary corrections, if any were required. I and my helpers received these samples of water at the laboratory. When the sample was received the date and hour of reception at the laboratory and the serial number was placed on the certificate which accompanied the sample and the same number was placed on the bottle containing the sample.

5028 These serial numbers appear at the left hand of the various tables. Under the head of turbidity, the star indi-

cates a decided turbidity; the section mark, a very decided turbidity; the dagger, a distinct turbidity; the double dagger, a very slight turbidity; the vertical parallel, a slight turbidity.

5029 (States manner in which the presence of sediment and color were determined. See pages 5028 to 5034 for explanation of these tables.)

5033 (Motion by Mr. Jeffries to strike out the testimony of witness in explanation of samples and answer thereto by Mr. Todd and Judge Springer.)

5037 The tables which I have read in evidence, beginning with No. 1 and ending with No. 38 contain analyses of water samples taken during the year 1899. I have made averages of all results of my analyses of the samples collected from each of the points under consideration during the year 1899. Table "A" entitled "Streams Examination, Sanitary District of Chicago, Sanitary Water Analyses, Parts per Million, Averages of Results for year 1899," is the one I prepared and represents the general averages for the year 1899 of the figures appearing in tables No. 1 to 38 inclusive.

5040 Table read in evidence.

5042 Table "B" "Streams Examination, Sanitary District of Chicago, shows averages of Results for year 1900," report of Arthur W. Palmer, University of Illinois.

5046 The averages for the tables numbered 1 to 80 are given in tables "C" and "D" respectively. Table "C" contains averages of results for the period of June, July, August and September, 1899, and is made from the detailed analyses appearing in tables No. 1 to 32 inclusive and was prepared in the same manner as Tables "A" and "B."

5048 Table "C" read in evidence.

5050 Table "D" shows averages of results for June, July, August and September, 1900.

5052 Table "G" is a table made by bringing together some of

the averages of tables C and D covering the two four-month periods namely June, July, August and September, 1899, and June, July, August and September, 1900, also showing the highest and lowest figures of various determinations made during the periods in question.

5054 Table H comprises a comparison of the general average of all the work during the years 1899 and 1900 which appear in the tables numbered 1 to 80 inclusive. It was made for the purpose of comparing the condition of the water as between the two years as covered by the examinations made which appear in tables numbered 1 to 80 inclusive.

5055 Tables 95-A, B, C, D, E, F and G contain results of various determinations of dissolved oxygen in samples of water from the various points in the Illinois river and some of its tributaries and the Mississippi river. These determinations ranged from the latter part of April, 1899, until about the middle of October, 1900. These determinations were made from a separate set of samples taken at the same time. In some cases they were collected simultaneously with the large samples that were used for chemical analyses and in all other cases all shipped samples were collected at the same time as the bacterial and chemical samples.

5056 Most of the samples, determinations upon which are recorded in these tables 95a to 95g inclusive, I collected myself and analyzed myself. Samples which were not collected by me—and they include only a portion of the samples collected at Grafton—were collected for me by a collector who had been specially instructed.

5057 In the series of three columns, for which the heading is "Milligrams per liter," represented by the ordinary abbreviation, capitals "M. G." for milligrams, there appear the results of determinations upon duplicate samples in the first two columns, and the average of these two determinations in the third column, save where in a few cases, from lack of time, duplicate determinations were not made. In the next column is given the temperature of the water, which determination was

made by the one who took the sample. In the next column, under the general heading "Per Cent of Saturation," are figures which represent that portion of the possible quantity of dissolved oxygen which was actually contained in the water. That is, it is well understood that under the conditions of exposure to the atmospheric there will be modified somewhat by atmospheric pressure, modified very largely by the temperature of the water. The proportion of oxygen which the water may hold in solution varies, and the maximum which can be held in equilibrium in solution at any given temperature is called the saturation figure, and when the water is fully saturated it is regarded as holding 100 per cent of dissolved oxygen, which means all that the water can normally, under the given conditions, retain in solution.

5058 The succeeding determinations down through all the tables, including 95g were made in the same way as that I have just explained, excepting that a few of the analyses or determinations of dissolved oxygen included in these tables were made by the well known Winkler method. (Witness explains process of making examinations by said method.) In the column headed "Remarks," in some instances is the statement, "Test of Keeping Qualities."

5059 The explanation of this is that in some cases even where the work was done on the spot, and for the reason of getting some information as to what changes take place during transportation from the point of collection to the laboratory, samples collected simultaneously with those in which the determination was made as the water came from the stream, were set aside and kept sometimes ten or twelve hours, sometimes until the next day, sometimes two days. The test of keeping qualities applies to this, for the reason that it is found that waters containing notable quantities of organic matters frequently suffer a loss of dissolved oxygen when the samples are allowed to stand out of their natural environment, that is,

5060 taken out from the stream in which they normally are found, or from which they have been collected. If there

is a great diminution of the quantity of dissolved oxygen, then the keeping qualities are regarded as being inferior to what they are in case there is less diminution on standing. (Witness explains how samples were collected and shipped.) With reference to my statements concerning saturation of the water with dissolved oxygen, a reference to the column in which the data under this head is given, shows at once that the figures there are in many cases considerably above 100. For instance, under the Illinois river water at Henry above the dam for 1899, under date of August 17th, the first in that series, the percentage shown in the last column under saturation is 220.88. This shows that the water is highly supersaturated, the supersaturation takes place by reason of the fact that the chlrophyl containing organisms with which the river water at such seasons especially abounds, under the influence of sunlight, give off streams of oxygen, which may be seen coming up through the water and under these conditions, the water naturally
5061 dissolves much more oxygen than it could under these conditions dissolve from the atmosphere, and this oxygen for a time remains in the water, although on long standing it undoubtedly would be given off in part into the atmosphere, down to the saturation figure of 100 per cent, and also might in part be utilized by the organic matters in the water, and so the proportion be reduced. (These tables will be found on pages 5062-3-4-5-6-7 and 8.)

Objection by Judge Springer to the reading of the tables in question.

When these samples were analyzed in these tables just put in evidence, I was acting as collector, analyst and investigator of the conditions of the water in the Illinois river and tributaries and the Mississippi. I began this work at my own instance, but such portion of it as is included in the tables here under consideration, tables 1 to 80 inclusive, and the tables of averages, were begun as a result of the conference held March 15, 1899, at the city hall, which conference has been described in part by myself and more fully by Dr. Gehrmann in his testi-

mony. I undertook the work on dissolved oxygen myself for the purpose of getting information concerning that particular constituent or condition of these waters as a part of the general investigation, in progress, of these various waters.

5070 The results of our determinations of dissolved oxygen in some 400 samples of water from the Illinois river have shown that the waters of the Illinois river at all times contained a considerable percentage of the quantity of oxygen which was required for saturation, and that at times it contains much more than the saturation figure; indeed, occasionally at certain points it contains even more than double the saturation quantity. The supersaturation of the water with oxygen, if we may so term it, is due to the liberation of oxygen by the chlrophyl containing micro-organisms, and other minute plants which are very abundant in the waters of the Illinois at certain seasons of the year. In fact, oxygen evolving organisms seem to be always present and almost always active in these waters.

5071 Many of the determinations have been made upon the spot, but inasmuch as circumstances rendered it impracticable for us to make very extensive series of determinations in this way, the samples of water were, throughout a considerable portion of the time, shipped to the laboratory and the determinations of dissolved oxygen made there ordinarily in about 20 hours after the time of collection, but sometimes not until 40 or 48 hours had elapsed from the time of collection. These shipped samples gave results which are always less than the saturation figure, except on a few occasions, when the original water was highly supersaturated with oxygen. The exceptions noted from the general diminution of dissolved oxygen during transit, were occasioned by the treatment of some of the samples with mercuric chloride, in which cases there appeared no diminution in the proportion of dissolved oxygen, as the mecuric chloride prevented such changes in the water, as under other circumstances brought about such a decrease of the oxygen contained in solution. Comparison of the results of determinations made upon the spot with those made upon duplicate

samples which were either shipped to the laboratory or kept under similar conditions to those involved in shipping, show that there was in all cases a notable diminution of dissolved oxygen during the time which elapsed between the time of collection, and the time of making the examinations. Consequently, it is certain that the actual content of dissolved oxygen in all these waters was in reality greater than the results here recorded. There was but one case in which a greater percentage of dissolved oxygen was found in the sample which had been kept. This determination is recorded in the bottom line upon table 95a, where a sample of the Illinois river water was taken at Averyville, Aug. 17, 1899, at 6:30 p. m. and examined Aug. 18, 1899 at 7:05 p. m. approximately 24 hours after the time of collection. This abnormal condition will be considered more in detail farther along, when we discuss the conditions at Averyville. Dissolved oxygen in the water of the Illinois river, at its mouth at Grafton: The series of determination dissolved oxygen which appear in the tables 95a to 95g, show that during the period January 4th to June 27th, 1900, the percentage
5072 of saturation in the Illinois river water ranged from 43.1 to 95.7 the average being 76.47 per cent for the entire series of 141 shipped samples. As is seen in the date columns, the determinations were made upon samples shipped to the laboratory in usually about 24 hours after collection. The minimum 43.1 per cent was found in the case of four samples collected May 16th, and examined May 18th. In no other case was less than 52.7 per cent found, and indeed, in but five other samples was less than 61 per cent dissolved oxygen found. Dissolved oxygen in the waters of the Mississippi river at Grafton: A parallel series of determinations of dissolved oxygen in the waters of the Mississippi just above the mouth of the Illinois was made upon samples collected at the same time, that is, within a few minutes and shipped and examined under similar conditions. The details appear upon tables 95e and 95f, inclusive. The degree of saturation in these samples ranged from 55.78 per cent to 108.84 per cent, the average for the entire

series of 127 samples being 82 per cent. Comparison of the data obtained from these two series of shipped samples, shows that the waters of the Illinois contain 93.2 per cent of the quantity of dissolved oxygen found in the waters of the Mississippi. I mean by that, that in these shipped samples there was little more dissolved oxygen in those which came from the Mississippi river than was found in those which came from the Illinois river, the relation being as 92.2 in the Illinois to 100 in the Mississippi. This was the year 1900. Analyses made upon the spot (see tables 95c, 95d and 95e) show that both the Illinois river water at Grafton and the Mississippi river water at Grafton frequently contain a greater proportion of dissolved oxygen than is required for saturation, but each of them also frequently contains less dissolved oxygen than the saturation figure required. In general it is true, that the waters of the Illinois do not retain their dissolved oxygen so long as do the waters of the Mississippi, that is, the dissolved oxygen diminishes more quickly and to a greater extent in the water of the Illinois than it does in the water of the Mississippi although the difference between the two river waters in this respect is not very great as may be seen by a study of the data of the tables.

5073 The upper Illinois: In the Illinois river at La Salle, just above the town upon August 16, 1899, we found the water eighteen inches below the surface just saturated with dissolved oxygen, the actual figures being 100.12 per cent to 100.36 per cent in samples taken at different points across the stream. Sample of the water taken at the same time, but examined 24 hours later contained but 75.7 per cent of dissolved oxygen, while still another sample collected at the same time as the three above mentioned, but kept 41 hours, contained but 58 per cent of the amount required for saturation. The evidence would seem to show that during sunshine, oxygen was being evolved by the vegetable life in the water with sufficient rapidity to keep the water saturated, yet when the conditions were changed by placing the sample in the dark such action ceased,

and the oxygen began rapidly to disappear. Similar conditions were found with respect to the water of the Illinois and Michigan canal at La Salle. The water at the upper basin at La Salle was, before the opening of the sanitary canal, in a better condition ordinarily, than was the water of the Illinois river at this point, for the reason that the canal above La Salle was fed from the Fox river and other streams. The records with respect to the water in this place, as given in table 95a show that the water in its original condition contained 102.42 per cent while after standing 24 hours, it was reduced to 62.26 per cent. Upon August 17th, somewhat striking conditions were found at Henry. The samples were taken above the dam at 1:15 p. m. upon a bright day. The temperature of the water, 32 degrees C. being very nearly as high as that of the air, which in the shade was 34 degrees. A sample of the water taken one inch below the surface was found to contain considerably more than twice the amount of oxygen required for saturation, presuming of course, the saturation figure should be that for an equilibrium between the oxygen of the atmosphere and that dissolved in the water. The water was full of minute vegetable organisms, and it had a very distinct yellowish green tint. The temperature of the top inch of water was 32 degrees C. or 89.6 Fahrenheit. The quantities of dissolved oxygen found by the Levy method in this water were 220.9 per cent and 211.4 per cent respectively. Samples taken at the same time and place, but at eighteen inches below the surface had a temperature of 28 degrees Centigrade, and were found by the Levy method to contain dissolved oxygen corresponging to 200 per cent of saturation and 208.3 per cent of saturation respectively. While the determinations made upon the same samples by the Winkler method showed 208.35 per cent. A sample collected at the same time and kept until the next day, the analysis being made 24 hours after the time of collection, during which time the sample was kept in the dark, was found to contain 110.1 per cent of the saturation figure. At the same time and place a collection was also made at two feet

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from the bottom or ten feet below the surface. At this depth also the water was found to be supersaturated but far less so than the water at the surface above the dam and it is probable that the water at two feet from the bottom was comparatively sluggish in motion, and the conditions of temperature and of illumination by sunlight were not the same as those prevailing in the strata of water nearer to the surface. The dissolved oxygen in the water very near the bottom disappeared much more rapidly and was reduced far more proportionately than that in the water taken near the surface. The percentage remaining at the end of 24 hours being about 47.42 per cent. This difference as to retention of dissolved oxygen was undoubtedly due to a difference in either the Plankton or the other organic matters contained in the water in these two different strata.

Averyville: Several visits were made to Averyville, just above Peoria, for the purpose of making determinations upon the spot, and some of these developed quite interesting results as upon July 21, 1899, the water 18 inches below the
5075 surface was found late in the afternoon, to contain 171 per cent of the saturation figure of dissolved oxygen and the water was still supersaturated with oxygen when samples which were kept in the dark were again examined 18 hours and 24 hours later, after the lapse of this time, the figure being 115 to 117 per cent respectively. The quantity of dissolved oxygen in the samples collected at the same spot the following morning were found to be only 87.8 per cent, but during the morning it increased slightly to 95.6 per cent at 10:10, reaching 111.7 per cent at 12:20 p. m., and 114.3 per cent at 1:10 p. m., at which time the examinations were stopped by the necessity for catching a train. Samples collected at the same time were kept over for two days, and it was found that the quantity of dissolved oxygen had diminished in 48 hours from 114 per cent to from 38 to 40 per cent. (See in Illinois river, Averyville, July 2, 1899, at bottom of table 95a.) On August 17th, late in the afternoon the quantity of dissolved oxygen found in the water at the depth of 18 inches at Averyville was 80.5 per cent, while

the water coming from about two feet above the bottom in fourteen feet of water contained 74 per cent of the saturation figure. A sample of the water taken eighteen inches below the surface at 6:30 p. m. which was kept until the next day was found to contain a considerably higher quantity of dissolved oxygen than the sample which was examined at the time of collection. The determination on the spot gave 80.49 per cent, and that made 24 hours later gave 97.53 per cent. It may be that this is an error, but it is possible that in this case some more hardy oxygen evolving organisms than usual were contained in the water, and that during the following day, which was excessively hot, light was not entirely excluded from the sample; or the original content of oxygen may possibly have been quite different, for as is evident from the records for the 19th, when this point was again visited, the water earlier in the afternoon was supersaturated. Upon August the 19th at 12:30 p. m. a sample taken 18 inches below the surface contained 184 per cent; another taken at the same time but three hours later contained slightly more than 200 per cent, and a sample collected at four o'clock contained 215 per cent. Another collected at 4:25 contained 215.7 per cent, while the samples of water collected one and one-half hours later at the same point and under the same conditions were found to contain 95.6 per cent dissolved oxygen. During the time that these examinations were made, the surface of the water was marked here, there and everywhere, with patches of blue-green scum the size of a man's hand, apparently consisting of masses of filamentous algae. The current was quite rapid and these patches were about two or three feet apart in various directions. The samples were taken under such conditions as to exclude these floating matters from the sample of water upon which the test was made. The sun was shining very brightly and the temperature was very high. These examinations were made at the Averyville bridge where the river is very narrow and the current rapid. Between this point and Henry, about 38 miles above, the river spreads out to a considerable width,

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forming a series of so-called pools, lakes or lagoons, in which the current is very sluggish. In these broad stretches the conditions of depth, spread of surface, temperature and rate of movement are in the summer season especially, favorable for the development of plant life and the water consequently so teems with green and green-blue organisms that oxygen is evolved in great abundance, in fact may frequently be seen coming from the floating plants in streams of minute bubbles. During the middle of the day when the chemical activity of the sun's rays is at the maximum, the evolution of oxygen naturally will be at the maximum and the water then becomes supersaturated, but as the sun sinks towards the West, the action slackens and the excess of oxygen begins to disappear; partly perhaps by diffusion into the atmosphere, but undoubtedly in the main through absorption by the organic matter either living or dead, contained in the water, and in part by the cessation of the evolution of oxygen through the agents just referred to. The water which was found to be supersaturated at Averyville doubtless received its oxygen mainly at some distance above, and the rather sudden drop from 215 per cent to 95.6 per cent was in all probability due to the fact that a new body of water which in

the late hours of the afternoon had not been exposed to
5077 such vigorous action as prevailed earlier in the day began to reach the point of collection. This change may have also been due to the fact that as evening approached the sun was in part obscured from the particular point at which these examinations were made, by dropping below the high wooded bluffs which line the west bank of the river in this vicinity. Later in the year, that is upon October 16, 1899, another series of examinations were made in Averyville, but at this time the conditions were entirely different. The quantity of dissolved oxygen reached but 74.5 per cent to 77.5 per cent. Examinations which were made during January, 1900, gave similar results to those mentioned for October, 1899. Examinations made in June, 1900, showed figures which were consider-

ably below those obtained in July and August of the preceding year.

It is unfortunate that we did not have an opportunity to make determinations in 1900 upon the same dates as in 1899, for in June the season is not sufficiently advanced to bring about the conditions which are commonly encountered in the latter part of July and the middle of August. The results obtained in October, 1900, were practically identical with those obtained in October, 1899, which would seem to imply that the opening of the drainage channel has not materially changed the conditions with respect to dissolved oxygen at this point and for this season of the year. Dissolved oxygen just below Peoria: A few examinations made at Wesley City have always shown that the water of the river at this point contains far less than the saturation quantity of dissolved oxygen, a result due of course to the fact that so much sewage is discharged into the river about two or three miles above. Somewhat similar conditions were found with respect to the water at Pekin. The effect of a bright sunlight is strikingly shown by comparison of the figures obtained upon August 18th, in the middle of the morning with those obtained August 19th late in the afternoon, the figures for the morning being 24 per cent; those for the afternoon averaging about 82 per cent. Examinations of water collected early in the morning of August 19th at Havana, 30 miles below Pekin showed about one-third as much dissolved oxygen as would correspond to the saturation figure,
5078 while later in the day determinations by both the Levy and the Winkler method made at Copperas Creek dam and at Lancaster Landing—points between Havana and Pekin —showed considerable excess of dissolved oxygen. The weather was hot, 100 degrees to 108 degrees Fahrenheit in the shade, and there was considerable plankton in the water, much of it appearing to consist of filamentous and other algae. Dissolved oxygen in the water of the Drainage Canal: Several determinations were made of the dissolved oxygen of the waters of the Sanitary canal itself. Upon August 13, 1900, an examination was made

of the water in the upper end of the Sanitary canal at Kedzie Avenue. At 5:15 in the afternoon, a sample taken 18 inches below the surface was found to contain 29 per cent, and a little further down the canal, that is, at the Belt Line bridge at 5:40 o'clock it was found to contain 28.2 per cent. Upon June 29, 1900, at 5:00 o'clock in the afternoon, this water just above the Bear Trap Dam at Lockport was found to contain 10.9 per cent of dissolved oxygen, while at 200 yards below the dam, after the water had been agitated with air in its escapes from the higher level of the drainage canal to the bed of the Des Plaines river below, the aeration had been sufficient to bring the proportion of dissolved oxygen up to 55.5 per cent of the saturation figure. Upon August 14, 1900, similar determinations showed that the water above the dam contained 5.9, and that below the dam 70 per cent of dissolved oxygen. At Joliet, examinations made upon June 30, 1900, showed 27.8 per cent of dissolved oxygen just above dam No. 1 while just below the dam where the water has fallen 12 or 13 feet, the percentage of dissolved oxygen was found to be 81.28. In making these determinations, due care was exercised to prevent any minute bubbles of air being retained by the water which was made the subject of the examination. The entire pipette was filled with the water and was allowed to stand for a few minutes until such bubbles as were contained in the samples collected in the upper part of the pipette, and were allowed to escape. The results obtained at Lockport and at Joliet show strikingly the effect of agitation of the water with air in falling over the dam.

5079 A single determination made upon the water of the Fox river at Ottawa, August 20, 1899, showed the water of this tributary to be quite supersaturated. It contained 128.35 per cent of dissolved oxygen. The water of the Illinois and Michigan canal just above Channahan was examined upon August 21st and was found to contain three per cent of the saturation figure of dissolved oxygen. At this time there was practically no water flowing in the bed of the upper Des Plaines below Joliet, as at Joliet all of the flow both from the Des

Plaines river above and from the Illinois and Michigan canal was carried down the north bank of the river in the canal itself.

5080 Plate No. 1 was prepared by me and is a representative of certain of the averages which appear in table A, which averages have been made from the detailed data of tables No. 1 to 38 inclusive. (Objection by Mr. Jeffries.) Plate will be found on page 4082.

5084 I identify Plate No. 1 as a chart which I prepared to show graphically some of the results which are given in detail in tables No. 1 to 80 inclusive, and the averages which are shown on table A heretofore read in evidence. This particular plate No. 1 shows graphically the proportions of chlorine, oxygen consumed, nitrites, free ammonia, albuminoid ammonia, and total organic nitrogen as determined by my analyses, set forth in detail in tables 1 to 80 inclusive, and particularly as shown in the form of averages in table A. In order that the significance of the figures of table A, as shown graphically by means of the curves and columns of plate 1, may be fairly understood, I will as I proceed, state briefly the general significance which pertains to each constituent there represented, as we proceed with the discussion of the plate. First, the chlorine. This substance is contained in water in combination with various basic elements, but chiefly in the form of sodium chloride or common salt. Chlorides occur in very small quantities in all soils, and hence are present in small proportions in the waters of streams, ponds, lakes and so on, in their natural condition, and in a greater quantity are found also in wells, particularly in many artesian wells, and in salt springs. Most animal matters, and especially various animal secretions contain more or less chlorides, and chlorides are constant in considerable constituents of sewage. In the sewage they are derived not only from the various animal secretions and particularly the urine contributed to sewage, but also are introduced in various manufacturing wastes, as the wastes from soap factories, packing houses and so on. They are also contained in kitchen wastes,

being derived from the liquids which have been in contact with food during the preparation of foods for the table. The only natural causes of change in the proportions of chlorine aside from such concentration as may result from long continued hot weather during the season of minimum flow, would be its decrease by dilution with waters which contain less, or its increase by mixing with waters and other liquids as sewage, and so on, which contain more. The chlorine introduced into streams in the form of chlorides remains unchanged (if it were at any time introduced in other forms, it might change, but it is not ordinarily so introduced.) That is, is not in any way removed, absorbed or destroyed, but finds its way finally into the sea into which the stream or streams finally discharge. The de-
5085 termination of the proportion of chlorine consequently is an index to the total quantities of chlorides introduced into the stream from whatsoever source, above the point at which the determination in question is made. Referring now to the curve for chlorine upon the plate, we note that a very large proportion, namely 124.2 parts per million, was contained in the water of the Illinois and Michigan canal at Bridgeport, on the average for the period, May to December inclusive, 1899. This period it should be understood is referred to throughout in the discussion of Plate No. 1. The proportions of chlorine at Lockport and Joliet, respectively, 29 and 33 miles below Bridgeport, respectively, are smaller than the proportion at Bridgeport. The reduction in proportion at Lockport being due to slight dilution along the course of the Illinois and Michigan canal; that at Joliet being due to the dilution effected by mixing of the waters of the Des Plaines river with the discharges from the Illinois and Michigan canal, just above the point at which the Joliet samples were taken. From this point on down to Peoria there is shown continuous and considerable decrease in the proportions of chlorine. The decrease between Joliet and Morris, 25 miles below, due to the introduction of the discharges of various small streams into the Des Plaines, but mainly due to the introduction of the waters of the Kankakee

river, which latter was found for this period to contain on the average, 3.9 parts of chlorine per million. Below Morris there are small streams discharging water into the Illinois, which brings about a reduction in the proportion on the way to Ottawa. At Ottawa the discharge of the Fox river brings about a very considerable reduction in the proportions of the chlorine, so that at La Salle the proportion is 47.3 as against 59.4, the proportion contained at Ottawa. The Fox river at Ottawa during this period containing on the average 5.8 parts of chlorine per million. There is but slight dilution, as indicated by reduction of chlorine, between La Salle and Henry, but
5086 beyond Henry again, a notable decrease in the proportion of chlorine occurs, to Averyville, where the proportion is 41.1 parts per million. The decrease resulting from the dilution effected by the discharges of various small streams, and in part by the underground flow of land water into the river. This underground flow is known to be considerable along the entire stretch of the Illinois river between La Salle and Beardstown and is particularly considerable between Peoria and Havana, and in times of low water may have quite an appreciable effect in diluting the waters in the stream, an effect which of course was more considerable before the flow and the initial dilution were increased by the inflow of lake water secured by the opening of the Chicago main drainage canal in January, 1900. The increase of chlorine between Averyville and Wesley City resulted from the contribution of Peoria's sewage to the river and in small part probably was due to the inflow of the water of certain saline artesian wells and springs. From this point, that is Wesley City just below Peoria, there was a continuous and considerable diminution in the proportions of chlorine at all points down to the mouth of the river at Grafton, and the final discharge into the Mississippi river contained chlorine in the proportion of 18.5 parts per million. The next curve which we may consider represents the oxygen consumed. Oxygen consumed is the quantity of oxygen required for the burning of the organic matters contained in the water, or rather the quantity

of oxygen required for combination with and oxidation of those organic matters contained in the water which are readily affected by the process used in these determinations, for it is well known that not all of the organic matters are affected, or at least are not completely oxidized by the chemical processes employed. It is evident from the curves which merely represent the figures in the table of averages in table A that the organic matters which at Lockport required a great deal of oxygen for their consumption, namely 37.7 parts per million, were so affected by dilution and natural oxidation as to appear in much smaller proportions at Morris and at Ottawa. A notable increase occurs between Ottawa and La Salle, but the organic matters then below La Salle diminish in proportion until we reach Averyville, where the proportion was 11.1 parts per million. Below Averyville there occurs an increase until we pass Pekin, and from
5087 there on down to the mouth of the river at Grafton, occurs a gradual but definite diminution, the quantity of oxygen consumed by the waters as they pass from the Illinois into the Mississippi being 9.9 parts per million. Free ammonia, or saline ammonia as it is variously designated, is naturally present in small proportions in surface waters, being introduced into them by the washings of the air by the rain and from surface soils, by the rain water, which in times of storm flow in part over the surface to the streams. It is contained in comparatively great quantity in fresh sewage or sewage which is in the first stages of putrefaction. In the sewage it has come in part from the sanitary wastes of the household, including the discharges from human beings, but comes also from other household wastes, and from the discharges of other animals. It comes in part from discharges of manufacturing wastes and industrial wastes of various sorts, including stock yards wastes, refuse from gas works, and the decomposition products of the same and so on, and is produced by the putrefactive changes to which organic matters from all these sources are naturally susceptible. The

large proportions of nitrogen as free ammonia contained in the waters of the canal at Bridgeport and Lockport respectively are represented at the left hand of the table and by the figures 17.16 and 15.58 which appear in table A of averages. The diminution in proportion between Lockport and Joliet is due to dilution by the waters of the Des Plaines, and between Joliet and Morris, to the dilution referred to above under the discussion of chlorine and oxygen consumed, namely, dilution effected mainly by the introduction of the waters of the Kankakee, and is in part effected by the natural decomposition or changes to which this substance is subject in streams and other surface waters. Between Ottawa and La Salle there is a very great diminution, namely from five parts per million to 2.65 parts per million. This diminution being effected in part by dilution with the waters of the Fox river and other but minor tributary streams, and in part due to nitrification which takes place vigorously in the stretch of stream between Ottawa and La Salle, and it may in part be due also to assimilation by the plant life,

which is abundant in this part of the river, and in part
5088 due to its conversion to free nitrogen which escapes in
part into the air. On the other hand, there may at times be a tendency toward an increase of the proportions of free ammonia as a result of the de-oxidation of nitrates and nitrites, which takes place when these substances in water are in contact with various organic matters. Between La Salle and Henry there is further diminution in the proportions of free ammonia notwithstanding the fact that just below La Salle the sewage of La Salle is, by the final discharge of the Illinois and Michigan canal, introduced into the Illinois river, and that the sewage and wastes of Peru also are introduced at this point. Between Henry and Averyville, there takes place a more considerable diminution in the proportions of free ammonia, this being undoubtedly due to the natural destruction of ammonia or its oxidation into nitrates and nitrites or its assimilation by the plant life of the river, or to all of these causes together. Now I notice a mistake in the figures given upon this plate. The figure

in the table of averages is correct and the curve is drawn to proportion all right, but the figures there above Henry in the plate is put 2.56 and it should be 2.156—perhaps a minor correction but one it is well to have made. Beyond Averyville there is an increase in the free ammonia to Wesley City, a slight further increase to Pekin, and from there on down to the mouth of the river, continuous decrease—slight it is true—until we reach Havana, but beyond Havana more considerable in proportion until we reach Kampsville, where the proportion is only slightly greater than that contained in the water as it is discharged into the Mississippi at Grafton, 31 miles below, where the proportion is .221 parts per million. Nitrites: Nitrites as contained in surface waters may be derived from the washings of the air by the rain; the leachings from the surface soils with which the fallen rain has been in contact on its way to the surface streams, which discharge it into ponds or rivers, and is also produced by the oxidation of nitrogenous organic matters derived from these or other sources and contained in the surface water, be it that of ponds or streams.

5089 The nitrites constitute a stage or represent a stage in the series of decomposition which convert organic matters finally into the comparatively unobjectionable mineral matters which are chiefly carbonic acid and nitrates. The comparatively small proportions of nitrites in the upper river down to the neighborhood of Morris shows that this second stage of natural purification is to this point but beginning, but the great increase below Morris witnesses to the fact that from here on this highly important feature of nature's purification processes is efficiently active. The gradual diminution of the nitrites on the way down the river from Ottawa to Averyville would indicate a gradual progressive exhaustion of the food supply for the organisms which are responsible for this oxidation and thus serves as evidence that the purification is proceeding. The proportions of nitrites contained in the water may at times also be increased by the reduction of nitrates which reduction at times proceeds beyond this stage, and brings about the liberation of nitrogen in

the form of nitrogen gas, the element, or may proceed further to the stage of ammonia, and so increase the proportion of the latter. The nitrites decrease in proportions from Pekin on down to Grafton, and this indicates considerable improvement in the sanitary condition of the water during its passage from Pekin to the point of discharge into the Mississippi river at Grafton. Total organic nitrogen: This determination, made by the Kjeldahl process, represents the total proportions of nitrogen contained in the water in combination in organic matters. The nitrogenous organic matters are contained in all soils in some quantity, but they are the most significant and constant constituents of sewage and include all sorts of animal refuse, tissues, fecal matters, constituents of the urine, household wastes and manufacturing wastes of various sorts, particularly those of animal origin, but also those of vegetable origin. Nitrogenous organic maters too, are essential constituents of all living things,

great or microscopic, both vegetable and animal. It is
5090 substances of this class in part which serve as the nutrients upon which bacteria thrive and multiply. The proportions of nitrogen as total organic nitrogen, that is the total nitrogen contained in organic matters, are shown by the figures of table A, and represented by the line upon plate 1 as being very considerable in the waters of the Illinois and Michigan canal, both at Bridgeport and at Lockport, the quantity diminishing between Lockport and Joliet, diminishing again very considerably between Joliet and Morris, and again diminishing on the way to Ottawa, but beyond Ottawa increasing in proportion on the way to La Salle and Henry, below which there is again a decrease to Averyville. The decrease between Joliet and Ottawa is partly due to dilution by the introduction of the waters of various tributaries, but in very large part is due to the natural destruction of these organic matters, and their conversion into more innocous forms, partly into mineral matters, partly into the organic matters of the vegetation of the river. The increase on the way to La Salle and Henry is due to the introduction of sewage by means of the Big Vermillion river, and the sewage of La Salle

and of Peru. The increase below Averyville on the way to Wesley City is due to the introduction of Peoria's sewage and refuse. Below this point, there occurs at first slight, but then a more considerable decrease in the quantities of total organic nitrogen on the way down to Beardstown, below which point there is a very slight decrease down to the mouth, where the proportion contained in the water as it is discharged into the Mississippi was during this period 1.037 parts per million. Albuminoid ammonia: The albuminoid ammonia varies somewhat in conformity with the variations of the total organic nitrogen, although the quantity is but from 40 to 50 per cent that of the latter. Its significance is similar to that of the total organic nitrogen, but the total organic nitrogen represents all of the nitrogen that is contained in the organic matters that is as constituting part of the tissues, living or dead, as well as various products of vital activities of living organisms, while the albuminoid ammonia represents only the nitrogen. Of such part, about one-half of these substances, as is comparatively easily affected by the chemicals and processes used in the albuminoid ammonia determination. Comparison of the waters of the Illinois with those of its tributaries and those of the Mississippi and the Missouri are made in groups 2 and 3 of plate 1. The various columns show the comparative proportions of total organic nitrogen, albuminoid ammonia and free ammonia contained in, and the oxygen consumed by the waters of the more important tributaries of the Illinois river, the waters of
5091 the Mississippi river above the mouth of the Illinois and the waters of the Missouri river just above its mouth. The columns in all cases representing the figures given in table A. It appears that during this period the waters of the Illinois at its mouth at Grafton, contained more free ammonia than those of the Mississippi and the Missouri and considerably more than those of its tributaries, except the Big Vermillion, the Illinois and Michigan canal not being considered. On the other hand, the columns show that the waters of the Mississippi and the Missouri contain considerably more total organic nitrogen

and albuminoid matters than did the waters of the Illinois, while the oxygen consumed by the waters of these two streams was nearly twice as great as that consumed by the water of the Illinois. In these respects, too, the columns show that the water of the Illinois river at its mouth compares favorably with the waters of its several tributaries. The Mississippi at Alton: The curves of group 4, plate 1, referring to the cross-section of the Mississippi river at Alton represent the averages of analyses of samples of water taken at the five points across the Mississippi at Alton, about sixteen miles below the mouth of the Illinois. It is evident from the consideration of the data, tables 23 to 27 inclusive, and the averages of table A, and as graphically shown by the curves of plate 1, that the waters of the Illinois do not mix thoroughly with the waters of the Mississippi, but chiefly pass down along the Illinois shore, and that the proportions of organic matters contained in the Mississippi river water are greater than the proportions of the same substances contained in the Illinois river water. The chlorine and ammonia, on the other hand, being higher in the Illinois river water at Grafton than in the waters of the Mississippi river at Alton or Grafton. The Mississippi at Chain of Rocks, or Mitchell: The waters of

the Missouri river during the period here considered, did
5092 not average so high in chlorine as did the waters of the

Illinois, but they contain an enormous amount of suspended matters, and notably greater quantities of various objectionable organic matters. From the data of tables 28 to 31 and the averages of table A, exhibited in group 5, plate 1, it would seem that at the Chain of Rocks the waters passing down the west bank and beside the intake tower consist mainly of Missouri river water and contain much larger proportions of organic maters than do the waters of the Illinois. Further comparisons: A consideration of the analyses of the individual samples given in tables 28 to 31 shows that the proportions of the nitrogenous organic matters never during the given period were so great in the Illinois river water as they were in the Missouri, and that the minimum proportion of these matters in

the Mississippi and in the Missouri river water never reached quite the low point that they did in the water of the Illinois river at Grafton. The general conclusion from the consideration of these data, which, however, it must be remembered cover simply the period from the beginning of May, 1899, to December 31, 1899, is that the water discharged from the Illinois river is in these respects in purer condition than the water of the Mississippi river just above Grafton, or the water of the Missouri river at Fort Bellefontaine, or West Alton, and that it is in most respects quite similar to the waters of the larger tributaries of the Illinois. Table G gives the specific data. I prepared plates II and III and they are based on some of the averages which appear in table B heretofore read in evidence and which shows the results of analyses of water taken at the points indicated between January 1st and October 1st, 1900, the details of which appear in tables No. 39 to 80 inclusive.

5093 (Objection by Mr. Jeffries to the introduction of the plates which are reproduced on pages 5094 and 5095.)

5096 Plate II is similar to Plate I in that it shows the proportions of various significant constituents contained in the waters of the Illinois and its tributaries, and the Mississippi at Grafton, Alton and the Chain of Rocks and the Missouri at Fort Bellefontaine, for the period January 1st to October 1st, 1900. That is, the nine months immediately subsequent to the opening of the Chicago main drainage channel. The effect of the dilution of the Chicago sewage with the lake water before discharging it into the Des Plaines and the Illinois river is shown by the analyses made during the year 1900. The data of these analyses appear in tables 39 to 80 inclusive, and the averages are brought together in table B. The features of Plate II are similar to those of Plate I but differ in that the proportions of the various constituents are not the same. These conditions being caused in the main so far as the samples from the Illinois river are concerned by the dilution effected by the opening of the Chicago main drainage channel. Discussion of this plate in detail is hardly necessary or especially profitable for

the reason that the period covered is not the same as that covered by the figures and lines of Plate I and for the further reason that a consideration of all such data as are included in the representations of Plate II, which are strictly comparable with the figures and lines of Plate I, are discussed and are represented by columns and curves in plates which are shortly to be considered. It is a well known fact that the waters of streams vary greatly at different seasons, both as to the volume of water and the content and nature of substances carried by the water. These seasonable variations are particularly important in the cases of some of the streams of the Mississippi valley and especially so for the Illinois, the Missouri and the Mississippi. Although the entire series of analyses for the year 1900 does not correspond as to the time and season with the entire series of analyses for the year 1899. These two seasons overlap during the summer months, namely the four months, June, July, August and September, during which period the most important physical features are the comparatively small volume of flow and the comparatively high temperature, not only the atmosphere but of the water itself, features which are especially important with reference to the Illinois river. In consequence of this overlapping, the data during this period for the two different years, namely, June, July, August and September, 1899, and June, July, August and September, 1900, are fairly and reasonably comparable with each other. For
5097 the purpose of making this comparison, I have prepared averages of the data of the Illinois made during June, July, August and September, 1899, that is before the opening of the main drainage channel and similar averages from data obtained from analyses made during the same four months in 1900 or immediately after the opening of the main drainage channel. The data appear in detail in tables 1 to 80 inclusive, and the particular averages in question appear in tables C and D respectively. Plate IV was made by me. The data represented upon it appears in the form of averages in tables C and D which were heretofore read in evidence and the details from

which the averages were made appear in tables 1 to 80 inclusive. (The introduction of said plate was objected to by Mr. Jeffries, and is copied in evidence at page 5099.)

5100 Plate IV is one of a set running from IV to XV inclusive, which have been prepared for the purpose of representing graphically the average proportions of some of the more significant constituents of the waters of the Illinois river, its tributaries, the Mississippi and the Missouri, as they appear in the tables of averages C and D, representing the detailed analyses of tables 1 to 80 inclusive, covering the period June, July, August and September, 1899, the year prior to the opening of the Chicago main drainage channel, and the same period, that is, June, July, August and September, 1900, the year subsequent to the opening of the Chicago main drainage channel. In order that the situation and the full significance of the data which are represented by the plates be realized, reference should be made to the statement of the reasons for selecting the various points at which the collections of samples were made and to the map which shows the relative situations of these points of collection. In each plate of this set, IV to XV inclusive, there are two sets of curves or two sets of columns, one set representing the data for the summer of 1899 and the other representing the data for the summer of 1900. By following the various lines of the curve, and the proportions of the various constituents which they represent, it is made evident that the conditions in the river have changed considerably since the opening of the main drainage channel. The portions of the curves and sets of columns at the left hand of each plate representing the conditions prevailing between Chicago and Lockport are of course modified more greatly than the other parts of the curves for the reason that until January, 1900, it was the old or Illinois and Michigan canal only which carried the discharge of Chicago sewage into the Des Plaines river valley, while since the opening of the drainage channel, the sanitary canal itself

5101 carries not merely undiluted sewage and stock yards drainage, but a very large proportion of diluting lake

water. Inasmuch as the Illinois and Michigan canal is still mainly fed from a fork of the south branch, which is not yet flushed with lake water, we find that the proportions of the various constituents are still excessive in the waters of the old or Illinois and Michigan canal, both at Bridgeport and at Lockport. It is to be remembered that the discharge through the Illinois and Michigan canal is now much less than it was formerly, for since the opening of the drainage channel, the old canal is used chiefly for transportation and not particularly as a sewer and the pumps at Bridgeport are supposed to raise only such fluid as is required to maintain a serviceable depth for commerce. The average flow in the Illinois and Michigan canal prior to 1900 was from 35,000 to 36,000 cubic feet per minute. In 1900 it varied during the year, but the average was 26,700 cubic feet a minute. In 1901, the pumps were in operation only during seven months, beginning the latter part of April and reaching to the latter part of November. During this period of seven months, the average rate at which liquids were raised from the south fork of the Illinois and Michigan canal was 23,000 cubic feet per minute; the average for the entire year, which is not a true average for the time of operation, however, being 13,800 cubic feet per minute. The figures of tables Nos. 40 and 41 in which the data of analyses of samples from the Illinois and Michigan canal at Bridgeport and Lockport for the year 1900, are set forth, reveal occasional variations of considerable magnitude. These variations are chiefly due to the fact that the pumps at Bridgeport which feed the Illinois and Michigan canal are situated but a few rods within the mouth of the south fork and that the diluted sewage which, on its way through the south branch to the drainage channel, passes the mouth of the south fork, sometimes enters a short distance within the mouth and is thence pumped into the old canal. The short duration of such occasional conditions during which comparatively dilute sewage is pumped into the Illinois and Michigan canal, ac-
5102 counts for the fact that the variations are less frequent

and less considerable at Lockport, 29 miles below, for the reason that on the way the mixing of the more concentrated sewage ordinarily raised, and the more dilute sewage occasionally introduced by the pumps, is more or less perfected. At Joliet where the discharges through the two canals and that from the upper Des Plaines river have come together, there is frequent and considerable variation in the proportions of organic matter and other impurities contained in the waters of the Des Plaines river, partly in consequence of variations in the flow of water from the Illinois and Michigan canal through the use of locks, partly from occasional closing of the gates at the Bear Trap dam, thus shutting off or reducing the flow of the more dilute sewage from the drainage channel. The accumulation of sewage in the Chicago river, which follows a stoppage or reduction of the flow through the drainage channel is another cause of variation, for when the gates are again opened the sewage discharged is for a time necessarily less dilute than it would otherwise have been. The variations at Joliet result in large part also from incomplete commingling of the waters, for the discharge from the old canal entering by the south or east bank at Lockport and at Joliet generally passes down beside that bank for some considerable distance, but at times when the flow from the drainage channel is reduced, it often extends further out into the stream or possibly may entirely cross the river bed. The variations which appear in table 44 are largely due to the facts just above considered. Upon Plate IV there is shown, first, general curves representing the proportions of chlorine and of nitrogen as albuminoid ammonia in the waters of the Des Plaines and the Illinois rivers at different points between Chicago and the mouth of the river at Grafton. For the purposes of this study the Illinois and Michigan canal and the sanitary canal are both regarded as being part of the one system which includes these canals, the Des Plaines river and the Illinois river stretching from Chicago to the Mississippi at Grafton. Comparison of the two curves representing the chlorine shows a much more considerable diminution of the

proportions of chlorine contained in the water flowing through the bed of the Des Plaines river at Joliet, in 1900 than 5103 in 1899. This is obviously due to the dilution of Chicago sewage with lake water which passes through the drainage channel. The continuous diminution in content of chlorine between Bridgeport (in both years, following the Illinois and Michigan canal as far as Joliet) and the mouth of the river at Grafton, is of course due merely to dilution. The average quantity of chlorine contained in the natural surface waters of the regions in question has ranged from two to three parts as in the water of Lake Michigan, to as much as five or six parts as frequently found in the waters of such streams as the Fox, the Kankakee and the Sangamon. The waters which pass through the drainage canal contain a considerably smaller portion of chlorine than is contained in the waters passing through the Des Plaines and Illinois river valley, for the reason already noted that the sewage carried by the Illinois and Michigan canal, and discharged by it into the Des Plaines river at Lockport, and just above Joliet, is still very concentrated. Moreover, in and about Lockport and Joliet there are various saline artesian wells. There are sewers and manufacturing establishments which discharge into the old canal or the river between the collecting point at Lockport and that at Joliet. From Joliet down, the river there is a slight fall in chlorine for 1900 as we reach Morris, and the subsequent apparent increase in the content of chlorine at Ottawa, notwithstanding the inflow of the waters of the Kankakee above Morris, are in some measure misleading, and untrustworthy, for the mixing of the two streams is at these points still incomplete as subsequent work has shown, and to the incomplete mixing of the main body of water from the drainage channel with the waters of the various tributaries is due many of the variations in both directions which appear in the results for 1900 for the several points between and including Joliet and Ottawa. Various cross-section determinations made at La Salle, Averyville and Grafton have shown that at these several points the mix-

ing is complete. Particularly at Averyville and Grafton, which we may regard as critical points, determinations of chlorine in samples taken at a number of poin[illegible] across
5104 the river have invariably shown that in these localities there is no difference in the chlorine content of the water anywhere between the two banks. At the mouth where the Illinois discharges into the Mississippi river, this water contains less chlorine than is found in it anywhere between that point and Chicago, except in the sanitary canal itself. The proportion contained in the water at the mouth of the river in 1900 was very slightly greater than that contained during the corresponding time in 1899. The curves representing the nitrogen as albuminoid ammonia show for 1899 a very rapid diminution in quantity as we pass from Bridgeport down the stream to Ottawa. Beyond Ottawa there is a notable increase, reaching the maximum at Henry, but beyond that point there occurs a considerable diminution to Averyville or Peoria. Below Averyville, that is at Wesley City and Pekin, the quantities of nitrogen as albuminoid ammonia were greatly increased as a result of the discharge of sewage and wastes from distilleries, cattle sheds, glucose works and such plants at Peoria and Pekin. Below Pekin again there is a slight but constant diminution until we reach the mouth of the river at Grafton. The curve for 1900 shows that there were much smaller quantities of albuminoid matters contained in the waters of the sanitary canal and in the waters of the Des Plaines river at Joliet, and as we proceed down the stream from Joliet there is a decrease which reaches the limit at Ottawa. Beyond Ottawa, the albuminoid nitrogen increases until Henry is reached beyond which point it diminished to Averyville. A slight increase occurred as we passed from Averyville to Wesley and Pekin and so on to Havana. Beyond Havana there is a gradual but continuous diminution until at the mouth of the river at Grafton the proportion of albuminoid nitrogen contained in the water discharged from the Illinois into the Mississippi was notably less in 1900 than it was in the year 1899. Comparison

of the Illinois with the Mississippi and Missouri, group 2, on Plate IV, represents first, comparison of the chlorine contained in the waters of the Illinois as it discharges into the Mississippi at Grafton, for the summer months of 1899 and for the summer months of 1900. The proportions are stated in tables
5105 C and D, and represented in Plate IV by two columns at the lower right hand corner. Mere inspection of these columns is sufficient to show the relation of these proportions and to make manifest the slight difference as to chlorine content in the waters of the Illinois at its mouth between these two years. Second, a comparison of the chlorine contained in the Mississippi above the mouth of the Illinois for like periods in 1899 and 1900. This is shown by the two columns next to the left of those referring to the Illinois river water. Inspection of the figures in the tables make manifest—and the two columns in the plate show graphically the differences as to chlorine content in the Mississippi river water between these two years, and show that the proportion of chlorine in the Mississippi river water during this period of 1900 was considerably greater than during the similar period of 1899. This difference as to chlorine content between the two years was due doubtless to the fact that the water in the upper Mississippi river was at a lower stage during the summer of 1900 than it was during the summer of 1899. Upon Plate XVII which will be here-
5106 after introduced in evidence, the stages of water in the Mississippi river for the years 1899 and 1900 are represented. Third, a comparison of the chlorine contained in the waters of the Missouri river near the mouth for the same periods. The figures in tables C and D show that the waters of the Missouri river contained a much higher proportion of chlorine during the summer of 1900 than during the corresponding season of 1899, but it must be noted that the period covered in 1899 is somewhat shorter than that for 1900, as in the earlier year the collections from the Missouri began July 10. The facts as represented in the tables of averages are shown in the plate by the columns labeled "Missouri" and serve to repre-

sent the considerable difference between the proportions for these two periods. Fourth: Comparison of the content of albuminoid nitrogen in the Illinois river for 1899 and 1900, referred to in the general statement above, is shown graphically in this group, and these differences appear to the eye at once upon inspection of the columns. Fifth: Comparison of the content of nitrogen as albuminoid ammonia in the water of the Mississippi river above the mouth of the Illinois. The second set of columns under the title, "Nitrogen as Albuminoid Ammonia," shows a slightly smaller proportion contained in the water of the Mississippi for 1900 than was contained during the same period of 1899, and shows further that there was considerably more albuminoid nitrogen in the waters of the Mississippi river during each of these periods—that is both 1899 and 1900, than was contained in the waters of the Illinois river in either of the seasons in questions. Sixth: Comparison of the content of nitrogen as albuminoid ammonia in the waters of the Missouri. The figures which appear in tables C and D, show that during the summer of 1900 the proportion was greater than during the summer of 1899 and shows further that more than twice as much albuminoid ammonia or albuminous substances was contained in the water of the Missouri river in each of these years as was contained in the water of the Illinois river at Grafton and very considerably more than was contained
5107 in the waters of the Mississippi river. These facts as they appear in the tables of the averages C and D, being represented graphically by the two columns at the left hand of the group 2, in Plate IV. Cross-section of the Mississippi at Alton and at Mitchell, or Chain of Rocks, group 3, on Plate IV, represents the content of chlorine and of nitrogen as albuminoid ammonia in the waters of the Mississippi river at four points across the stream at the Chain of Rocks, opposite the intake tower of the St. Louis waterworks. From consideration of the curves which represent the averages appearing in tables C and D, it is made evident that the content of chlorine and of albuminoid nitrogen was considerably greater upon the Missouri

side of the river than it was upon the Illinois side, and shows further that there was a greater difference between the two sides of the stream at the St. Louis pumping station during the season of 1900 than there was during the same period of the preceding year, that is, the year 1899. These differences between the proportions of chlorine at the different cross section points at the Chain of Rocks and also the seasonal variations of the chlorine at these points are exhibited in Plate XIV which is to be hereafter introduced, and we will give a short description of that hereafter. Plate V was made by me from the same data that was the basis of the lines and columns upon Plate IV. The description is the same but there was something more. We show upon Plate V, cross-section proportions at Alton, as well as cross-section proportions at the Chain of Rocks and the columns upon Plate V represent the chlorine only for those various points and not also the nitrogen as albuminoid ammonia, which said Plate V is copied in evidence on page 5109.

5110 Plate VI was made by me and represents graphically some of the averages which appear in tables C and D, which averages are based on the detail analyses, shown on tables 1 to 80 inclusive, or such part of these latter tables as cover the period June, July, August and September of 1899 and 1900. (Objection to said plate by Mr. Jeffries.) Said Plate VI is copied in evidence on page 5114.

5115 Plate VI was made by me for the purpose of facilitating a realization of the significance of certain averages which appear in tables C and D, and in this respect is supplementary or rather complementary to that portion of Plate IV which represents the proportions of nitrogen as albuminoid ammonia. It has the different lengths of the column to show the differences between the two years. The columns in this plate show in addition to the total albuminoid nitrogen, also that portion of nitrogen as albuminoid ammonia which is derived from albuminous substances contained in solution, and the difference between the black portion and the total heighth of each column

represents the proportion of nitrogen as albuminoid ammonia derived from that portion of the albuminous substances which are in suspension in the waters. As all of the Plates IV to XV inclusive, this plate covers the periods June, July, August and September, 1899 and 1900. The successive shortenings of the columns as we proceed from near to the left hand side of the plate to the right hand, shows the successive steps of decrease of nitrogen as albuminoid ammonia as we proceed down these streams from the neighborhood of Chicago, that is Bridgeport and Lockport to the mouth of the Illinois river at Grafton, and shows moreover, the notable increase in the proportions of these substances contained in the waters of the Illinois river just below Peoria. Moreover, the differences between the two seasons, that is the period June, July, August and September of 1899, and the same months of 1900, readily appear on comparison of the right hand column with the left hand column in each set of two across the bottom of the plate. The very considerable difference between these columns showing the very considerable decrease in proportions of albuminoid nitrogen effected for the season 1900 by the dilution consequent upon the opening of the Chicago main drainage channel, and the discharge of lake water through it into the Des Plaines valley. That this has not during the period in question brought any notable increase in the proportions of ni-
5116 trogen as albuminoid ammonia in that portion of the waters of the Mississippi which passes down from the vicinity of Grafton to the Chain of Rocks near St. Louis toward the Missouri bank, is evident from an inspection of the columns of group 4 and group 2. Plates VII and VIII were made by me and represent certain data which appear in the tables of averages in tables C and D, the detailed analyses of which appear in tables 1 to 80 inclusive. These two plates represent in general similar features to those already referred to in the description of Plates IV and VI, but the particular substances

represented on Plates VII and VIII are the total organic nitrogen, that derived from substances which are in solution, that derived from substances which are in suspension and the sum of the two for the real total. Plates VII and VIII are reproduced on pages 5117 and 5118 respectively.

5119 The periods covered by Plate VII are the four summer months, June, July, August and September, 1899, and the same months of the year 1900. They are intended to illustrate, by a representation of the figures of the tables of averages C and D, the changes which take place along the course of the Illinois river and the Des Plaines river and the Illinois and Michigan canal and the Sanitary canal from Chicago to the mouth of the Illinois at Grafton, in the proportions of the total organic nitrogen, and also to show the relative quantities of total organic nitrogen in the water of the three streams, namely, the Illinois river, Missouri river, and the Mississippi river near the point at which these two streams come together, and to show the variations across the stream of the Mississippi river at Alton, and opposite the intake of the St. Louis waterworks at the Chain of Rocks, and to represent the difference between these two years for the period indicated. With reference to the effect of the opening of the Chicago main drainage channel upon the waters of the Illinois and such portion of the Mississippi river as extends from the mouth of the Illinois to the intake tower of the St. Louis waterworks: The considerable differences between the right hand and left hand column in each pair in Plate VIII show how much less was the content of nitrogenous organic matters as represented by the total organic nitrogen in the summer period referred to above, of the year 1900 as compared with the same period of the year 1899, the latter being the period before the opening of the Chicago main drainage channel and the former the period subsequent thereto.

5120 Inspection of the two columns at the lower right hand corner of Plate VIII shows graphically the relation between the figures which appear in tables C and D, representing

the average proportions of total organic nitrogen, and that contained in substances in solution in the waters of the Illinois in 1899 and in 1900. Inspection of the columns represented in group 3 serves to show that the proportions of total organic nitrogen contained in the waters of the Illinois river at its mouth at Grafton, in 1900 was very considerably less, in fact, but little more than half as much in 1900 as in 1899. Same comparison of the next two columns which represent the proportions in the Mississippi river shows that in it also the proportions for the summer period of 1900 were considerably less than during the same period in 1899, although the difference is not proportionately so great as in the case of the waters of the Illinois. The third set of columns in this group represent the conditions with respect to the total organic nitrogen in the waters of the Missouri river. These columns serve to represent figures which appear in tables C and D, and express the fact that in the waters of the Missouri river in 1900 there was a greater proportion of total organic nitrogen than in the preceding year, that is the same period for the year 1899, but to those there must be noted the fact that the period for the Missouri river in 1899 was not so long as the period for the year 1900, for the reason again that the collections in the Missouri river did not begin in 1899 until July 10th.

Cross-sections of the Mississippi at Alton shown in group 4, show that the proportions clear across the stream in 1900, were considerably less than the proportions of total organic nitrogen contained in the waters of the Mississippi river at this point during the preceding year, the year 1899. Consideration of the columns of group 2 show that the relative proportions at the different points across the stream at the Chain of Rocks were not much different in the year 1900 from what they had been in the year 1899, although the total proportions at each of the four points across the stream were less in 1900 than in 1899.

5121 Plate VII represents similar data by means of lines and curves instead of the columns, and will probably need

no further explanation than that just given in respect to Plate VIII. The total organic nitrogen referred to in these tables and in these plates and in the tables in which the figures represented upon the plates appear, is contained as a constituent of organic matters, particularly such organic matters as are contained in animal substances, and which are essential constituents of all living things, including micro-organisms, as well as all other and irrespective of size, of the animal or vegetable character, except that in general a greater proportion of nitrogen is contained in animal substances than is contained in most vegetable organisms or the substances in vegetable organisms which in particular contain the nitrogen in organic combination. It includes that just referred to above and in the earlier plates as nitrogen as albuminoid ammonia, and in general it is from two to three times as much as the latter. The dissolved organic nitrogen is of course derived from these nitrogenous organic matters which are commonly in solution in the water, while the total includes not only this, but also that which is contained in matters which are suspended in the water. These comparisons further give expression to the fact that the nitrogenous organic matters in solution which are here represented by the term "organic nitrogen in solution" are contained in the Illinois river water in greater proportion than in the waters of the Mississippi or in the waters of the Missouri, but it is noticeable that the difference between these streams has been considerably less during the summer of 1900 than it was during the summer of 1899. In the waters of the Missouri river there was somewhat more in 1900 than 1899, but the difference is slight. For the Mississippi and the Illinois, however, there are as represented, considerable differences indicating a better condition of their waters in this respect during the summer of 1900 than during the summer of 1899. The striking differences between these three streams with respect to the

5122 proportions of the nitrogenous organic matters becomes clearly manifest upon inspection of the unshaded portions of the columns of Plate VIII. I made Plates IX,

X and XI and they were made as representations of the figures appearing in the tables of averages covering the four summer months, June, July, August and September, 1899, and the same months in 1900, which averages appear in tables A and D, and represent the detailed data which appear for these two four-months periods, in tables 1 to 80 inclusive. Plates IX, X and XI reproduced on pages 5123-4-5 respectively.

5126 Plates IX, X and XI represent the proportions of nitrogen as free or saline ammonia and of nitrogen as nitrites contained in the waters of the Illinois and Michigan canal, the Sanitary canal, the Des Plaines river and the Illinois river at various points between Chicago and the mouth of the river at Grafton, except that the data which are given generally upon the single Plate IX are separated for presentation in the form of columns and appear, nitrogen as free ammonia upon Plate X and nitrogen as nitrites on Plate XI. After what has been said concerning similar plates representing other important constituents but little explanation is needed in order to understand the meaning and significance of the curves of Plate IX, or the columns of Plates X and XI with reference to the purification of the stream. The total organic nitrogen and the albuminoid nitrogen referred to in the descriptions of Plates IV, VI, VII and VIII represent largely waste organic matters which may be derived from either vegetable or animal sources or both. All vegetable and animal organisms contain as essential constituents substances which in their original condition and also in certain various stages of decomposition are classed as nitrogenous organic matters. Such matters are included in feces and urine, in waste from the household, in wastes from all industries which utilize plant and animal substances and products as well as in the vegetable substances contained in soils and which accumulate in swamps and in forests. Those substances which make sewage and animal waste in general offensive to the senses and dangerous to the health are, as a rule, nitrogenous organic substances, either living organisms or the products or wastes of living things. The natural processes of

purification of sewage and similar organic wastes involve the oxidation of these nitrogenous matters. The first stage in the purification process includes such a decomposition of these substances and the breaking down of the molecules of the complex proteid bodies, as results in the liberation of a portion of the nitrogen, together with the hydrogen in the form
5127 of ammonia. This may remain merely dissolved in the water, or it may unite with acids, particularly with the carbonic which in these decompositions of the organic matters may be formed simultaneously with ammonia, and thus appear as a salt of ammonia, or carbonate of ammonia. Ammonia is not in general contained in the surface waters in considerable proportions except it be derived from the sources above mentioned, or it be formed by the reduction of nitrates and nitrites when these substances under some conditions are in contact with decomposing organic matters. The proportions of free ammonia contained in the water of the stream or in sewage, indicates on the one hand the relative quantity of refuse matters contained, and shows the stage of decomposition or on the other hand, it may represent the relative proportions of reduction of nitrites and nitrates. In this reduction process a considerable portion of the nitrogen which was at one time present in the water in the form of nitrates or nitrites, may be wholly lost, so far as the possibility of analytical determinations are concerned, by conversion into the element nitrogen, which as a gas may in part remain dissolved in the water, or it may be discharged from the water into the air in a gaseous state. Referring to Plates IX and X, we may observe that in 1899 a considerable proportion of nitrogen as free ammonia was contained in the water of the Illinois and Michigan canal and that although the proportion contained in the Des Plaines river at Joliet was considerably diminished through mixing with the waters of the upper Des Plaines river, yet considerable proportions of free ammonia were found in the river as far down as La Salle, but that the diminution still proceeded as we passed down the river until we find the minimum at Averyville. Be-

low Averyville the free ammonia increased in proportion again, reaching the maximum at Pekin, diminishing then more rapidly and continuously until the mouth of the river at Grafton is reached. The curve for 1900 shows of course the effect of dilution with lake water in the sanitary canal, that is the proportions of nitrogen as free ammonia never were so great in the water flowing into the upper end of the canal and past the points between that and Grafton as they were in the preceding year in the Illinois and Michigan canal and the Des Plaines river and the Illinois river. Otherwise the curves show similar features, that is the very rapid diminution of free ammonia until we reach Averyville shows that the natural decomposition of the organic matters is taking place very vigorously in the upper reaches of the stream, but this action diminishes as we proceed down stream. The indication being that the diminution of the bacterial action is caused mainly by the exhaustion of the nutrients, that is, the supply of substances which are being converted by bacteria through ammonia into other innocuous forms of matter and which may be regarded as the food supply of the bacteria, is more rapidly diminishing. It is notable that the proportion of free ammonia increases again below Averyville, but afterwards diminishes until we find at the mouth of the river considerably less than elsewhere along the course of the stream and less during the summer of 1900 than during the summer of 1899. Upon Plate IX there are two curves and upon Plate X various columns representing the proportion of nitrogen as nitrites. Nitrites are oxidation products derived from the nitrogenous organic matters above referred to. In the conversion of objectionable and harmful nitrogenous organic matters into innocuous substances, the nitrites mark a stage following that which is indicated by the presence of the free ammonia. The curve for 1899 shows the maximum content of nitrites at Ottawa. From thereon considerable diminution occurs until we reach Averyville and Wesley but beyond that there is again an increase. We find the maximum at Pekin, beyond which there is a gradual

3128

decrease until we reach the minimum at the mouth of the river at Grafton. The two maxima indicate the two zones in the river at which the second stage of the natural purifying processes is most vigorously under way. Referring now to the curve for 1900, it becomes evident that the increase in the proportion of nitrites becomes marked very much nearer the source of the sewage, that is, since most of the sewage has been diluted before it is discharged into the Des Plaines river valley, those natural decompositions and oxidations of the organic matters which result in the formation of nitrites and subsequently nitrates, have begun vigorously at a point much nearer

5129 Chicago. The point at which the maximum quantity of nitrites is found during the summer of 1900 is again at Ottawa as during 1899. From there the curve varies in general in the same direction, but it is notable that the minimum is less than during the earlier season, and that the maximum never reaches the high proportion found in 1899. Consideration of the curves and columns shows that the zones at which the purifying action takes place with the greatest vigor are in the vicinity of Ottawa, and the stretch of river between Pekin and Havana, under both sets of conditions, that is, those conditions prevailing during the summer of 1899 and those prevailing during the summer of 1900 or both before and after the opening of the drainage canal. It is evident then that so far as the significance of nitrites is concerned, those purifying processes which effectively destroy the nitrogenous organic matters introduced into the waters of the stream either in sewage or in other ways, enter upon the decomposition earlier in their course of transit between Chicago and the mouth of the river, and the activities which bring about these changes reach their maximum at points no further down the stream since the opening of the Chicago main drainage channel than they did prior thereto. (Motion by Mr. Jeffries to strike out testimony of witness.)

5130 As to Plates IX, X and XI, a study of the various figures of the tables and the curves and columns of the plates

reveals the fact that in each of the summers in question, there was less nitrogenous organic matter contained in the water of the Illinois river at Ottawa just above the mouth of the Fox, than was in the Illinois river water at points farther down its course, except at Averyville, and at Grafton. This may in part result from incomplete mixing in the upper stretches of the river, but is undoubtedly due in part to the fact that organic matters of animal origin such as constitute the chief organic matters of sewage, are more easily susceptible to the putrefaction and oxidizing influences which bring about the purification of water, while vegetable matters, which constitute the greater part of the organic matters found in the natural waters of swamps and streams such as are contributed in larger proportion to the Illinois by its tributaries and by the run-off from its own slopes, are less easily decomposed and persist in the water of the lower river in greater proportion. Moreover, vegetation, particularly of the minute and floating forms, that is the plankton, is more abundant in the waters of the lower stretches of the river from La Salle down. The nitrites and nitrates produced abundantly in the waters of the upper part of the river through the decomposition of the nitrogenous organic matters of sewage are in turn utilized by the vegetation and in part their nitrogen is built up into more stable and less objectionable nitrogenous organic matters which remain floating or dissolved in the water and appear in the analytical results but must be regarded with much less disfavor and objection than would be accorded a like proportion of nitrogenous matters of animal origin.

5131 I identify Plates XII and XIII as plates which I made, to represent graphically certain averages which appear in tables C and D, which averages were made from those portions of tables 1 to 80 inclusive, which represent analyses of August and September, 1899, and the same months of the year 1900. Plates XII and XIII reproduced on pages 5132 and 5133.

5134 Upon Plates XII and XIII are shown curves and columns representing the proportions of oxygen consumed

by water in the Illinois river at various points, as indicated on the other charts or plates, and a comparison of the waters of the Missouri river near its mouth, the Illinois at its mouth, and the Mississippi just above the mouth of the Illinois, and cross-section determinations at Mitchell or the Chain of Rocks, on Plate XII and at the same points and also the cross-section at Alton, in Plate XIII. It is obvious from inspection of the curves and columns which represent the figures recorded in tables C and D, heretofore read in evidence, that the water in the upper stretches of the river contains a great deal more of such organic matters as are easily susceptible to oxidizing agencies, than does the water in the lower stretches of the river. The diminution in 1899 was very rapid until we reached Ottawa and Averyville, below Averyville the quantity of oxygen consumed increased owing to the discharge of sewage and wastes into the river at Peoria and Pekin. Below Pekin there is a continuous diminution in these matters until the mouth of the river is reached. Similar features appear when we consider the total oxygen consumed by matters in solution in the water, that is in the filtered water. The curve for 1900 shows variations at different points along the river and makes manifest the fact that the proportion of easily effected organic matters in the water is considerably less than during the corresponding season of 1899, though there is not such a great relative diminution along the course of the river, for the reason that the initial dilution through the operation of the sanitary canal at once decreases the proportions of oxidizable matters in or near to Chicago and there is consequently less opportunity for diminution on the way down the river because the proportions at the upper end are already less than they were in former times, that is times prior to the opening of the drainage canal.

5135 Group 2, Plate XII, represents a comparison of the relative quantities of oxygen consumed by the waters of the Illinois river, those of the Mississippi river and those of the Missouri river. It is evident that the waters of the Illinois river contain considerably less readily oxidizable matter in the

summer of 1900 than in the summer of 1899. In the case of the Mississippi river water it is evident that the proportion of oxidizable matters far exceeds that contained in the Illinois river water at the mouth, and that the proportion is practically the same for the two seasons, namely 1899 and 1900. In the case of the Missouri river water the proportion of oxidizable matters is essentially the same in 1900 as it was in 1899, but in both years it is very much greater than the proportion contained in the water of the Illinois river. On the other hand, comparison of the proportionate quantities of oxygen required by dissolved organic matters shows that there is less required by the waters of the Missouri river than by the waters of the Mississippi river or those of the Illinois river, this appearing from the columns which appear in Plate XIII. In 1899 as appears from this same group 3 of table XIII, the quantity of oxygen consumed by the waters of the Illinois river was considerably greater than in 1900, also by the Mississippi river water, more was required during the summer of 1899 than during the summer of 1900, but in each year the quantity required by the Mississippi river water was greater than the quantity required by the Illinois river water. In answer to the question of counsel,

I would say that the smaller proportions of oxygen re-
5136 quired by dissolved substances in the Missouri river water, notwithstanding the fact that the total oxygen consumed by the Missouri river water was greater than that required by either the Mississippi or the Illinois river water, was due to the fact that the substances in suspension in the Missouri river water were more considerable in quantity, required more oxygen for their oxidation than did the suspended matters in the waters of the Mississippi river or the waters of the Illinois river. Now group 3 of Plate XII and group 4 of Plate XIII show the relative quantities of oxygen consumed by water samples collected at the four points across the stream of the Mississippi river at the Chain of Rocks or Mtichell. It is evident that the water along the Missouri shore and in the vicinity of the intake tower contains much greater quantities

of organic matters than does the water which passes down near the Illinois shore. On the other hand, in this latter group it is apparent that the dissolved readily oxidizable matters contained in the water near the intake tower are less in proportion that those contained in the water near the Illinois shore. Group 2, of Plate XIII, representing the cross-section at Alton, shows that the proportions of oxidizable matters at various points across the stream were greater during the year 1899 than they were during the same period of 1900, both for the totals and for that in solution, and shows further that the proportions of total oxygen consumed and that consumed by matters in suspension, were greater as we pass from the Illinois shore down which the Illinois river water flows, toward the Missouri shore, where the water in greater proportion is that from the upper Mississippi river. Considering the evidence represented by the columns in group 1, and that of the curves in groups 2 and 3, Plate XII, and the columns of group 1 and those of groups 3 and 4 of Plate XIII, it appears that the water passing down near the Missouri shore and passing the intake tower of the St. Louis waterworks is much more nearly like the water of the Missouri river than it is like that of the Mississippi river in its upper stretches or the Illinois river in its lower stretches.

5137 I made Plate XIV and the data which are represented here by means of curves are contained in tables No. 1 to 80 inclusive, referring to the points named in the plate, which tables have been heretofore put in evidence. Plate XIV reproduced on page 5139.

5140 Plate XIV is supplementary to or complementary with Plates IV and V, which were heretofore put in evidence. It exhibits the differences between the proportions of chlorine at the different cross-section points at the Chain of Rocks, and also shows the seasonal variations of chlorine at these points during such periods, as the tables corresponding refer to, as indicated by the years marked upon the plate and the months and days appearing in the scale at the bottom thereof. The

small circles along the lines place the dates and show also the proportions of chlorine by their relation to the vertical scale at the side of the plate. There appears in these curves seasonal variations in the proportions of chlorine, and differences between the proportions of chlorine contained in the water of the Mississippi river at the four different cross-section points, opposite the intake tower of the St. Louis waterworks. It also institutes a comparison between the proportions just mentioned, and the proportions contained in the water of the Missouri river at West Alton, and serves further to illustrate the point previously discussed, that the water near the intake tower and near the Missouri shore at the Chain of Rocks is more like the water of the Missouri river than is the water passing down at mid-channel, or that passing down toward the Illinois shore in this locality, that is opposite the Chain of Rocks.

5141 Considering the various lines for 1900 which appear upon Plate XIV, it is evident that the proportion of chlorine contained in the water of the Missouri river at West Alton was greater at the dates indicated in January, 1900, than in February and that in March the proportion is considerably less than in either February or January. Proceeding on through such portion of the year as this curve represents, we find slight increases and slight decreases from time to time, but that in August there was a more considerable increase in chlorine than during several months preceding, and that after a decrease again in the latter part of August and in the early part of September, the proportion of chlorine increases considerably, to be followed by a decrease near the middle of September which was again followed by a very considerable increase near the end of September, the latter increase being followed by a more considerable decrease to a date early in October, which is stated in the table from which these data have come, but at which date the collection of samples from this river was discontinued. The dates at the bottom of the plate represent the dates at which the collections were made, but in order to avoid crowding at certain points in the scale at the

bottom of the plate some dates are merely indicated by lines, and not by figures. The figures all appear in table 73, which has heretofore been read in evidence. The line marked 1899 represents the data of the analyses for the same river, and the same point given in table 32, and covers the period July 10 to December 29, 1899. It shows similar seasonal variations, the content of chlorine in this case being lowest in the summer months and increasing during the fall and winter. Consideration of the other lines of Plate XIV shows that the waters passing down near the inlet tower of the St. Louis water-
5142 works and near the Missouri shore opposite, are subject to the same seasonal variations, as regards content of chlorine, as those just described, with respect to the water of the Missouri river at Fort Bellefontaine or West Alton, and show further that the water at these two points is more greatly like that of the Missouri river itself than is the water passing down at mid-channel, or that passing down toward the Illinois shore opposite the intake. I made Plate XV. It is based upon the figures given in tables C and D, which refer to the averages for the four summer months of June, July, August and September, 1899 and 1900, which averages were made from the detailed figures found in tables 1 to 80, inclusive, heretofore offered in evidence, and the columns of this table represent by their proportions the figures of the tables of averages referred to, namely tables C and D. The particular set of figures of tables C and D represented upon this plate are those which pertain to the waters of the Kankakee river, the Fox river, the Big Vermilion river, the Sangamon river, the Illinois river at Averyville, and the Illinois river at Grafton for the two periods in question, and have been brought together in this plate for the purpose of rendering easy a comparison of the relative proportions of the different constituents named upon the plate as contained in the waters of the tributary streams, and the waters of the Illinois river at Averyville and Grafton. (Mr. Jeffries objected to the introduction of all these plates.)

Said Plate XV reproduced on page 5144.

5145 Plate XV is intended to represent by means of columns the averages which appear in tables C and D, referring to the proportions of chlorine, of oxygen consumed, of nitrogen, as free and as albuminoid ammonia, and as nitrites, and the total organic nitrogen in the waters of several different tributaries of the Illinois, and to facilitate a comparison of the proportions represented by these figures of tables C and D, with the proportions contained in the waters of the Illinois at Averyville and Grafton. The comparison of these columns which merely represent the figures in the table of averages, renders evident at a glance the fact that the proportions of organic matters as represented by oxygen consumed, by albuminoid ammonia and total organic nitrogen, are even more considerable in the waters of the larger tributaries of the Illinois than they are in the waters of the Illinois at Grafton. Free ammonia and nitrites, however, are more abundant in the waters of the Illinois river at Averyville than in the waters of the tributary streams, but the waters of the Illinois river at its mouth at Grafton, contain less nitrogen as nitrites than is contained in the water of the Sangamon river, the proportion contained during this period of four summer months, June, July, August and September, 1900, being less than half as much as was contained in the corresponding period of 1899, and about three-fourths as much as was contained in the waters of the Sangamon river during the same period in 1900 and in 1899, and less than was contained in the waters of the Big Vermilion river during the corresponding period of 1899. The waters of the Illinois river at Grafton contain considerably less nitrogen as free ammonia during these four months in 1900 than was contained during the same period of 1899 and the proportions in both years were less than the proportions contained in the waters of the Big Vermilion river in either year, although the Big Vermilion river water contained less in 1900 than it did in 1899.

5146 Moreover, the proportions of free ammonia in the water of the Illinois at Grafton during this period in 1900 are

slightly less than the proportions contained in the water of the Sangamon for the same period and year and still more considerably less than was contained in the water of the Big Vermillion river, the Fox river, and the Kankakee river, during this same period. The proportions of nitrogen as nitrites and as free ammonia in the waters of the Illinois river at Averyville were very considerably greater than the proportions of nitrogen as nitrites or that as free ammonia in the waters of the Illinois river at Grafton in both years, and very considerably greater than the proportions of these substances contained in the waters of the Kankakee river during these periods and years. Consideration of the columns of group 4 representing the proportions of oxygen consumed, show that the waters of the Kankakee river and the Fox river required more oxygen than did the waters of the Illinois river at Grafton in both of these years, and that the waters of the Sangamon river required more oxygen in the year 1900 than did the waters of the Illinois river at Grafton in the same year. Comparison of the figures of group 5 shows similar facts with respect to the proportions of albuminoid ammonia, namely, that there was a greater proportion in the waters of the Fox river and in the Sangamon river in 1900 than in the waters of the Illinois river at its mouth at Grafton, and that in the year 1899 the proportions of nitrogen as albuminoid ammonia in the waters of the Kankakee and Fox were considerably greater than the proportions of these substances in the water of the Illinois river at the mouth. Similar facts appear from consideration of the columns of group 6, referring to the total organic nitrogen. In both years it appears that the water in the Illinois river at its mouth at Grafton contained less total organic nitrogen than did the waters of the Kankakee or Fox river, and that in the year 1900 the water of the Illinois at Grafton contained less total organic nitrogen than was contained in any of the tributary

streams here referred to, namely, the Kankakee, the Fox, the Big Vermilion and the Sangamon.

5147 I made plate XVI. It represents the discharge of water of the Des Plaines river at Joliet of the Chicago main drainage channel or sanitary canal at Lockport and of the Illinois river over the dam at Kampsville, 31 miles from the mouth of the river. The data relating to the flow of the Des Plaines river at Joliet, and the discharge of the sanitary canal at Lockport, were furnished me by the engineer of the Sanitary District, Mr. Isham Randolph, I believe is the name. The data concerning the discharge over the dam in the Illinois river at Kampsville were furnished me by the United States engineer in charge of the Kampsville dam and the improvement of the lower Illinois river, Mr. C. V. Brainard. (Objection by Mr. Jeffries.) Plate XVI reproduced on page 5149.

5150 The data which are represented by the curves of plate XVI, and which will be introduced in evidence, show the seasonal variations in the flow of the three bodies of water to which the plate refers, the curves being based upon the total measurements of the height of water, and computation of the flow corresponding to those heights. The points being the Bear Trap dam at the lower end of the Chicago main drainage channel at Lockport, Illinois, and the Des Plaines river at dam No. 1, Joliet, Illinois, and the Illinois river at the dam at Kampsville, 31 miles within the mouth of the Illinois river. Thus, in the early part of January, 1900, the flow in the Des Plaines river at Joliet is exceedingly small; the discharge from the sanitary canal which began on the 17th of January is represented by the lowest curve in the plate, by the underneath curve in the plate, and it is evident that the opening of the canal by the manipulation of the Bear Trap dam resulted in increasing the flow in the Des Plaines river at Joliet, and that throughout a very considerable portion of the year, that is, for much the larger part of the year, the flow at Joliet was but slightly greater than the dis-

charge of the drainage channel at the Bear Trap dam. The figures at the left hand side of the plate and those which appear at the right hand side also, indicate the volumes of water discharged per second, these figures applying to each one of the horizontal lines which is just beneath it. The line representing, where it touches the curve, the flow for the day so indicated. Thus, the line indicated by the figure 10,000 at the left hand corner of the plate crosses the line representing the discharge of

water in the Illinois river over the Kampsville dam at

5151 about January 16th, the precise date being given in the

tables of figures hereafter to be offered in evidence and shows that at or upon this date the discharge of the Illinois river at this point was 10,000 cubic feet per second. That there had been a somewhat sudden increase of the discharge upon a day or two preceding and an increased discharge for a day or two following this date. Continuing along the line of the curve, the variations, that is, the increases and decreases are at any point and every point indicated by the position of the curve, with respect to the horizontal lines of the plates, while the dates are indicated by the relative position of the curve with respect to the figures at the bottom of the plate, and certain vertical lines which have been drawn to facilitate the comparison. The flow is greatest at Kampsville in the latter part of March, that is, for this year 1900. This plate relates to 1900 altogether, the flow at that time being about 50,000 cubic feet per second. The figures represent the quantity of water going over the dam at Kampsville. I made plate XVII and it represents the figures supplied to me by readers of the gauge at the C. B. & Q. bridge

at Alton, Illinois. Plate XVII reproduced on page 5153.

5154 On plate XVII there are represented the stages of water

in the Mississippi river at Alton during the years 1899 and 1900, the chart being made from figures representing the heighth of water in the stream at this point each 24 hours during the year, the mean daily heights during each of the years indicated, namely 1899 and 1900, for the purpose of showing the seasonal variations in the height of the water, which figures bear a

direct relation to the volume of water flowing, and for the purpose of comparing the heights at various seasons during one year, with the heights during the same season during the other year. The figures on the left hand and right hand side of the plate represent the height of the surface of the water in feet with reference to the height of the sea at Biloxi, on the Gulf of Mexico, and indicates the relative stages of water in the Mississippi river at this point, namely, Alton, by reference to the lines indicating low water, and extreme low water respectively, as they appear near the bottom of the plate. The lighter line refers to the year 1900, and the heavier line refers to the stages of water during the year 1899. That this record as extreme low stage of water at Alton is a point 183.3 feet above the mean sea level on the Gulf of Mexico or the lake, whichever it is at Biloxi. The increase above this point then would represent the increased height of the water at the time stated at Alton.

5155 I have made other chemical analyses of the waters of the rivers of Illinois, and especially of the waters which have been under investigation since I took the stand as a witness in this case, than those about which I have already testified. As professor of chemistry in the university, it fell to me to examine many waters in connection with the instruction work of students, and also for the information of citizens, and also in connection with the work of the biological station of the university, which just at the time I began this work systematically, was located at Havana on the Illinois river. My first work upon the Illinois river with the exception of some few examinations made many years ago when I was a student, began in the summer of 1894, the result of which examinations,—comparatively few samples being examined, were reported by me to the president of the university in 1897. In the following year provision was made for a somewhat extensive series of investigations of the water supplies of the State, including not merely river waters and other surface waters, but also the ground waters, and the investigations at that time commenced, included an attempt at a

systematic study of the waters of the Illinois river.

5156 The State of Illinois made provision for more extended examinations of these waters. The legislative assembly of Illinois in the spring of 1897 passed an act establishing a survey of the waters of the State and by this act directed the trustees of the university to establish such survey and made appropriation for the work in this survey. The act is as follows: "An Act to establish a chemical survey of the waters of the State of Illinois, approved June 7, 1897, in force July 1, 1897."

Section 1. *Be it enacted by the people of the State of Illinois represented in the General Assembly*, that the trustees of the University of Illinois are hereby authorized and directed to establish a chemical and biological survey of the waters of the State in connection with said university.

Section 2. It shall be the duty of the university to collect facts and data concerning the water supplies of the State; to collect samples of water from wells, streams and other sources of supply, to subject these samples to such chemical and biological examination and analyses as shall serve to demonstrate their sanitary condition, and to determine standards of purity of drinking waters for the various sections of the State; to publish the results of these investigations in a series of reports to be issued annually, or oftener, to the end that the condition of the potable waters of the State may be better known, and that the welfare of the people of the various communities of the State may thereby be conserved."

5157 This is read from the laws of Illinois. I was directed by the Board of Trustees of the University of Illinois to proceed to carry out the directions in this act of the legislature. I proceeded to make the investigations indicated in section 2 of the act, that is, to obtain data and information concerning the waters of the State; to obtain samples of water from the various different sources, and subject these to examination and to prepare the results thus obtained in the form of reports to the president of the university and the trustees. The investigations which I at that time began, included the examination of samples of water drawn from Lake Michigan, delivered at tap in the city of Chicago; samples of water from the Illinois and Michigan

canal at Lockport; samples of water from the Kankakee river at Wilmington; from the Illinois river at Morris; from
5158 the Fox river at Ottawa; from the Illinois river at La Salle; from the Big Vermilion river, near La Salle; from the Illinois river at Averyville, or North Peoria; from the Illinois river at Havana; from the Spoon river at Havana; from the Illinois river at Kampsville; and later from the Illinois river at Grafton; from the Mississippi river at Alton and at Grafton and at Quincy. I selected the persons to take the samples of water and gave them the instructions.

5161 (Witness gives names of collectors at various points, tells how samples were collected and shipped, etc.)

5163 The samples were treated and analyzed in precisely the manner set forth in my testimony of the last three days, respecting the samples examined by me on behalf of the Sanitary District of Chicago. I made an entry of the ascertainments of those analyses on records made by me and will produce such record. (Witness produced certain tables entitled "Department of Chemistry, University of Illinois, Sanitary Water Analyses, parts per million," which constitutes a part of the report of the State Water Survey as made by the department of chemistry of the University of Illinois, approved June 7, 1897, and in force July 1, 1897, heretofore this day read in evidence, which tables were made by witness Arthur W. Palmer, Professor of Chemistry, University of Illinois, and which tables shall be hereafter known in this evidence as "Department of Chemistry, University of Illinois, A. W. P., table 1 to table 80 inclusive.")

MR. JEFFRIES: I object to the reading of the tables referred to in evidence. (Mr. Jeffries states reasons.)

These tables show the serial number, date of collection, date of examination, appearance, residue of evaporation, chlorine, oxygen consumed, nitrogen as ammonia, organic nitrogen and nitrogen as nitrites and nitrates, the examination running from January 4, 1897, to December 26, 1900, samples being collected about once per week. Places at which samples were taken, and

the page of record on which table is reproduced, showing result of such examination are as follows:

| Table. No. | Year. | Source of Water. | Point from which sample taken. | Record page. |
|---|---|---|---|---|
| 1 | 1897 | Lake Michigan | Chicago | 5166 |
| 2 | 1898 | Lake Michigan | Chicago | 5168 |
| 3 | 1899 | Lake Michigan | Chicago | 5170 |
| 4 | 1900 | Lake Michigan | Chicago | 5172 |
| 5 | 1897 | I. & M. Canal | Lockport | 5174 |
| 6 | 1898 | I. & M. Canal | Lockport | 5176 |
| 7 | 1899 | I. & M. Canal | Lockport | 5178 |
| 8 | 1900 | I. & M. Canal | Lockport | 5180 |
| 9 | 1901 | I. & M. Canal | Lockport | 5182 |
| 10 | 1900 | Sanitary Canal | Lockport | 5184 |
| 11 | 1901 | Sanitary Canal | Lockport | 5186 |
| 12 | 1897 | Des Plaines river | Lockport | 5188 |
| 13 | 1898 | Des Plaines river | Lockport | 5190 |
| 14 | 1899 | Des Plaines river | Lockport | 5192 |
| 15 | 1901 | Des Plaines river | Joliet | 5194 |
| 16 | 1901 | Des Plaines river | Joliet—west side | 5196 |
| 17 | 1897 | Illinois river | Morris | 5198 |
| 18 | 1898 | Illinois river | Morris | 5200 |
| 19 | 1898 | Illinois river | Morris | 5201 |
| 20 | 1899-00 | Illinois river | Morris | 5202-3 |
| 21 | 1899 | Illinois river | Ottawa | 5205 |
| 22 | 1900 | Illinois river | Ottawa | 5206 |
| 23 | 1901 | Illinois river | Ottawa | 5208 |
| 24 | 1897 | Illinois river | La Salle | 5209 |
| 25 | 1898 | Illinois river | La Salle | 5211 |
| 26 | 1899 | Illinois river | La Salle | 5212 |
| 27 | 1900 | Illinois river | La Salle | 5214 |
| 28 | 1897 | Illinois river | Averyville | 5216 |
| 29 | 1898 | Illinois river | Averyville | 5217 |
| 30 | 1899 | Illinois river | Averyville | 5219 |
| 31 | 1900 | Illinois river | Averyville | 5221 |
| 32 | 1901 | Illinois river | Averyville | 5223 |
| 33 | 1897 | Illinois river | Havana | 5224 |
| 34 | 1898 | Illinois river | Havana | 5226 |

| Table. No. | Year. | Source of Water. | Point from which sample taken. | Record page. |
|---|---|---|---|---|
| 35 | 1899 | Illinois river | Havana | 5228 |
| 36 | 1900 | Illinois river | Havana | 5230 |
| 37 | 1897 | Illinois river | Kampsville | 5232 |
| 38 | 1898 | Illinois river | Kampsville | 5234 |
| 39 | 1899 | Illinois river | Kampsville | 5236 |
| 40 | 1900 | Illinois river | Kampsville | 5238 |
| 41 | 1901 | Illinois river | Kampsville | 5240 |
| 42 | 1902 | Illinois river | Kampsville | 5242 |
| 43 | 1899 | Illinois river | Grafton | 5244 |
| 44 | 1900 | Illinois river | Grafton | 5246 |
| 45 | 1901 | Illinois river | Grafton | 5248 |
| 46 | 1902 | Illinois river | Grafton | 5249 |
| 47 | 1899 | Mississippi river | Grafton | 5250 |
| 48 | 1900 | Mississippi river | Grafton | 5252 |
| 49 | 1901 | Mississippi river | Grafton | 5254 |
| 50 | —— | Table missing .... | | |
| 51 | 1897 | Mississippi river | Alton | 5256 |
| 52 | 1898 | Mississippi river | Alton | 5258 |
| 53 | 1899 | Mississippi river | Alton, 100 ft. off Ill. shr. | 5260 |
| 54 | 1900 | Mississippi river | Alton, 100 ft. off Ill. shr. | 5262 |
| 55 | 1899 | Mississippi river | Alton, ¼ dis. from Ill. shr | 5264 |
| 56 | 1900 | Mississippi river | Alton, ¼ dis. from Ill. shr | 5266 |
| 57 | 1899 | Mississippi river | Alton, midstream | 5268 |
| 58 | 1900 | Mississippi river | Alton, midstream | 5270 |
| 59 | 1899 | Mississippi river | Alton, ¼ dis. from Mo. shr | 5272 |
| 60 | 1900 | Mississippi river | Alton, ¼ dis. from Mo. shr | 5274 |
| 61 | 1899 | Mississippi river | Alton, 100 ft. from Mo. shr | 5276 |
| 62 | 1900 | Mississippi river | Alton, 100 ft. from Mo. shr | 5278 |
| 63 | 1897 | Mississippi river | Quincy | 5280 |
| 64 | 1898 | Mississippi river | Quincy | 5282 |
| 65 | 1899 | Mississippi river | Quincy | 5284 |
| 66 | 1900 | Mississippi river | Quincy | 5285 |
| 67 | —— | Table missing .... | | |
| 68 | 1901 | Mississippi river | Quincy | 5286 |
| 69 | 1902 | Mississippi river | Quincy | 5287 |
| 70 | 1903 | Mississippi river | Quincy | 5288 |

| Table. No. | Year. | Source of Water. | Point from which sample taken. | Record page. |
|---|---|---|---|---|
| 71 | 1897 | Kankakee river | Wilmington | 5289 |
| 72 | 1899 | Kankakee river | Wilmington | 5290 |
| 73 | 1900 | Kankakee river | Wilmington | 5292 |
| 74 | 1898 | Fox river | Quincy | 5294 |
| 75 | 1899 | Fox river | Ottawa | 5296 |
| 76 | 1900 | Fox river | Ottawa | 5298 |
| 77 | 1901 | Fox river | Ottawa | 5300 |
| 78 | 1897 | Spoon river | Havana | 5301 |
| 79 | 1898 | Spoon river | Havana | 5303 |
| 80 | 1899 | Spoon river | Havana | 5305 |

5306 I made investigations as to the waters of the State of Illinois before the passage of the act of the legislature to which reference has been made. I began investigations in 1889 but did not begin systematic investigations of the Illinois river until the summer of 1894 when samples were collected at Havana and in 1895, under the provisions of an appropriation made by the legislature and assigned by the trustees of the University to the purpose, I made preliminary report which was published by the University in 1897 and covered all the work done under the provisions heretofore mentioned up to the end of the year 1896. (Said report offered as defendant State of Illinois Exhibit 23 for identification.) I made tables of averages made from the tables of detailed data just introduced in evidence as Department of Chemistry, University of Illinois, A. W. P. Table 1 to 80 inclusive, and State of Illinois Exhibit No. 23 for identification. Charts which are to be known in this investigation as "Department of Chemistry, University of Illinois, A. W. P. Plates V to XLII inclusive," illustrate in a graphic form the data contained in the tables which I have read in evidence and also in defendant State of Illinois Exhibit 23 for identification. Plates

5308 V to XVII are reproduced on pages 5309 to 5321 inclusive.

5322 Mr. C. V. Millar assisted me in making tables of analyses that I have read in evidence, up to the summer of

1900 and R. W. Stark right through the entire series.

5323 (Witness temporarily withdrawn from the stand.)

R. W. STARK, Examined in chief by Judge Springer.

Reside in Champaign, Illinois. Am a chemist employed in the State Water Survey. (Gives educational qualifications.)

5324 Assisted Professor Palmer in making chemical analyses which he prepared together with Mr. Millar and myself during the years 1897 to 1902.

5325 Table No. 1 down to and including table No. 21 put in evidence by Prof. Palmer were tables I assisted in making, and so far as the entries are made by me, are correct ascertainments of the analyses made by me at that time. The same applies to tables made by Prof. Palmer as a part of the sanitary survey of Illinois, covering periods from 1897 to the end of 1902, known as Department of Chemisty, University of Illinois, A. W. P. 1 to 80.

5326 PROF. ARTHUR W. PALMER, Resumed the stand for further direct examination by Judge Springer:

The data in table marked "Department of Chemistry, University of Illinois, A. W. P. 1," include the analyses of samples collected from the year 1897 until the year 1902. (Witness explains what is included in each column of the table, whch is shown by the table itself.)

5331 The dissolved oxygen determination covered a portion of the year 1897, the entire years 1898 and 1899 and a portion of the year 1900. The plates illustrating the dissolved oxygen to which I have referred have already been put in evidence. Plate V on page 5309 being a graphic illustration of the dissolved oxygen in the water of Lake Michigan drawn from a tap supplied from the four-mile crib opposite 14th street. The data represented in the curves of the plates already put in evidence is marked "defendant State of Illinois Exhibit No. 24 for Identification." These tables are known as "Department of Chemistry, University of Illinois, Plates V to XLV inclusive." (The tables marked 1 to 80 inclusive and heretofore read in evidence, on pages 5166 to 5305 inclu-

sive, contain certain determinations indicated on the said tables, except the dissolved oxygen determination, which is supplied by Plate V above referred to. Witness refers to tables and reads the determinations as indicated thereon, stating the places at which the samples referred to in the table were taken.)

5337 As to the analyses shown in tables 15 and 16, the witness states the object of taking the samples of the water of the Des Plaines river at Joliet just above dam No. 1 in the town of Joliet to be for the reason that observations of the waters at this point flowing through the bed of the Des Plaines river and variations in the analyses of samples collected at mid-channel at this point in the previous year, led witness to take these two sets of samples, one toward one bank and the other toward the other bank of the stream at Joliet, in order to secure the data respecting the different compositions of the water of the two sides of the stream, and with reference to a study of the mixing of the waters of the upper Des Plaines river, of the Sanitary canal and of the Illinois and Michigan canal after they had come together at Lockport, four miles above, and at the point a few hundred yards above that of collection at Joliet. This point was above that at which the sewers of Joliet discharge into the stream, although a portion of the Joliet sewage and manufacturing wastes mixes with these various bodies of water.

5338 There is a very considerable difference between the averages obtained from the analyses of samples collected at one side of the stream at this point, and the averages obtained from the analyses of the samples collected at the other side, these differences being due to the incomplete mixing of the several bodies of water which are passing down the valley of the Des Plaines at this point, or perhaps I had better say the bed of the Des Plaines river at this point. The variations being caused at this time by variations in the discharge at the Bear Trap dam, by variations in the quantities of sewage pumped from the south fork of the Chicago river into the

Illinois and Michigan canal and variations in the flow of the upper Des Plaines river.

5339 C. V. MILLAR, Examined in chief by Judge Springer: I reside in Joplin, Missouri. My occupation is that of assayer or chemist. (States educational qualifications.)

5340 Between 1895 and 1900 I made chemical analyses of the water at the University of Illinois in connection with Prof. Palmer.

5341 (States how samples were received, etc.)

5345 PROF. ARTHUR W. PALMER, Resumed the stand for further direct examination by Judge Springer:

The samples of water, the result of the analyses of which is shown on tables 21, 22 and 23, were taken at one point in the river at Ottawa where occurred a mixing of the waters of the Kankakee with the waters of the Des Plaines, which latter included the discharges from the Illinois and Michigan canal, the Sanitary canal and the waters from the upper Des Plaines. But the mixing not being complete this accounts for certain variations in the analytical data. This point was about 18 miles above the outlet of the old Illinois and Michigan canal. (From pages 5333 to 5356 the witness gives the location of the samples, number of times same were taken, etc., which data is all included in the table immediately preceding this testimony and found beginning with page 5166 of this record.)

5356 Stipulation that the samples of water taken at Joliet from the Des Plaines river, the Illinois river, and the Missouri river at West Alton and Chain of Rocks in the Mississippi river were taken in the manner stated and required, as shown by Sanitary District's Exhibit No. 11 for identification.

No. 869, The Rookery Building, Chicago, Ill., Nov. 16, 1903.

PROF. ARTHUR W. PALMER resumed the stand for further direct examination by Judge Springer:

5357 JUDGE SPRINGER: Defendant's Exhibit A, entitled "University of Illinois Chemical Survey of the Water

Supplies of Illinois, Preliminary Report, by Arthur William Palmer, S. C. D., Professor of Chemistry, published by the University, 1897," offered for identification. This may be used by either party hereafter as evidence in the case, or it may be referred to by witnesses or counsel, without being printed as part of the record.

This is my official report to the President of the University of Illinois.

5358 The data of the analyses show the general chemical character of the waters of Lake Michigan, and a comparison of the data for the different years with each other, and the averages for the different years with each other, show that the water of the lake is subject to no great variation as to the proportions of the various substances which are determined in the sanitary chemical analysis. They show that the water contains but a moderate proportion of mineral matters, that the organic matters are small in quantity as compared with many surface waters, and especially the proportions of nitrogen as free ammonia, as albuminoid ammonia, the total organic nitrogen, nitrites and also nitrates are present in a small quantity. The variations during the four years covered by the tables which have been read in evidence, namely, tables 1, 2, 3 and 4, of this series were in general, comparatively slight, and apparently were mainly caused by conditions which brought about variable discharges from the Chicago river, and from those sewers which empty directly into the lake and pass further out into the lake than they commonly do. They are also in part due to storms which stir up the sediment near the shore of the lake and near the cribs at which the intakes are located. The sediments being in the main such are natural to any considerable body of surface water, but including also a certain amount of refuse from the city and of dredgings from the Chicago river. The variations in no case vary considerably, and on the whole the water of the lake is to be considered as superior in quality to the water of all of the larger streams of Illinois and the vicinity.

5359 The determinations of dissolved oxygen in the water of Lake Michigan, upon samples drawn at the same time and place as those which were subjected to the sanitary chemical analyses showed that the waters of the lake were at all times fairly well charged, that is, generally saturated with dissolved oxygen.

The data of the dissolved oxygen determinations are included in Defendant's Exhibit No. 24 for identification and are represented by the curves on plate marked "A. W. P. No. V" which has heretofore been placed in evidence.

The averages of these tables are to be found at the bottom of each table. The tables of analyses No. 5 to 9 inclusive, include the results of examinations of samples of water taken from the Illinois and Michigan canal at Lockport just before it discharges into the Des Plaines river. The periods covered in these tables are the years 1897 to 1901 inclusive. In addition to the data in these five tables, I have made use of the averages for the year 1896 which are recorded in the Preliminary Report of the Chemical Survey of the waters of Illinois, which has heretofore been presented for identification, as Defendant's Exhibit A.

5360 The data reveals notable variations generally in April and March, the usual season of freshets, but for most of the year they show a somewhat remarkable uniformity in the proportions of organic matter.

5361 I have prepared some tables of averages of the analytical results at various points and they will be referred to hereafter as "Defendant's Tables of Averages, A. W. P. No. 1 to 15, inclusive." Table No. 1 shows the averages for the years 1896-7-8-9 of the waters of the Illinois and Michigan canal at Lockport, before the opening of the drainage canal and is reproduced on 5362 of record.

5362 Inspection of the yearly averages which appear in table No. 1 of this series shows that up to the time of the opening of the Chicago main drainage channel there were in most respects but slight variations from year to year, such changes

as did occur being in the direction of a small but constant increase of the nitrogenous organic matter.

Examination of the data of the analyses for the year 1900, which appear in table 8, and for the year 1901, which appear in table No. 9 reveal much greater and more frequent variations than occurred before the opening of the Chicago main drainage channel. The averages of the analyses of the waters of the Illinois and Michigan canal at Lockport for the years 1900 and 1901 appear in tables of averages No. 2, A. W. P., and will be found on page 5363 of record.

Comparison of the averages for the two periods shows that the relative proportions of organic matters were considerably reduced as a result of the diversion of a part of the sewage, and the new drainage channel, although the proportions of nitrogen as free ammonia became greater than before, a result
5363 which may be due to the effect of the greater dilution in facilitating the more speedy oxidation of the organic matter. The variations are mainly due to the fact that at times when the lake is high, or the discharge from the drainage canal at the controlling works is reduced comparatively pure lake water backs up into the south fork of the Chicago river in such volume that a more dilute sewage than usual is raised by the pumps at Bridgeport into the Illinois and Michigan canal, while ordinarily inasmuch as the south fork is not yet flushed out, the liquid pumped into the old canal, that is, the Illinois and Michigan canal, still consists mainly of the comparatively concentrated sewage from the stock yards district.

As compared with the analyses of the waters of Lake Michigan as given in tables 1 to 4, the waters of the Illinois and Michigan canal of course show evidence of the enormous quantities of refuse matters which are discharged into the Chicago river, and which thence pass into the Illinois and Michigan canal, this being revealed by the very much greater proportions of organic matters contained in the canal water as compared with those contained in the lake water.

The Defendant's Table of Averages No. 3, A. W. P. will be found on page 5364 of record and contains the averages of results for the years 1900 and 1901 from an examination of the waters of the drainage canal at Lockport, and consists of the averages of the determinations made as indicated by tables No. 10 and 11, found on pages 5184 to 5187 inclusive.

5365 The variations which appear in these analytical data are due in the main to variations in the volume of flow in the drainage channel, caused partly by differences in the lake level, partly by the partial closing of the gates or the raising of the Bear Trap dam at Lockport and also at certain times by the overflow of water from the Des Plaines river at the spillway into the main drainage channel itself. Further, they are caused in part by variations in the pumping at Bridgeport for when the Bridgeport pumps are not in operation a portion of the contents of the south fork enters the south branch of the Chicago river, and passes thence into the main drainage channel while when the pumps at Bridgeport are kept in operation practically all of the sewage of the south fork is discharged into the Illinois and Michigan canal, and enters the Des Plaines river below the point of discharge from the main drainage channel. Comparison of the figures in table of averages No. 3, with the figures appearing in tables of averages Nos. 1 and 2, show that the waters discharged through the sanitary canal are far more dilute than the waters discharged through the Illinois and Michigan canal, that is, the proportions of the various significant constituents notably those of the nitrogenous constituents, are very much less in the waters of the sanitary canal or main drainage channel, than they were and than they are in the waters of the Illinois and Michigan canal.

5366 Plate VI reproduced on page 5310 gives the flow for the year 1900 in the Illinois and Michigan canal at Bridgeport, the Des Plaines river at Riverside, the Drainage canal at Lockport and the Des Plaines river at Joliet. Plate VII reproduced on page 5311 gives a comparison of the relative vol-

ume of water discharged by these various streams or agencies at the same points for the year 1901.

5369 Table of Averages No. 4, A. W. P. gives results of analyses of samples of water referred to in Tables No. 15 and 16 on pages 5194 to 5197 inclusive, of record, and is reproduced on page 5370.

5371 (Witness explains cause of variations in the results obtained.) Table of Averages No. 5 is reproduced on page 5374 and gives the results of averages for tables No. 17, 18, 19 and 20 heretofore offered in evidence.

5375 Morris is the first station upon the Illinois river proper. At this point the waters of the stream consist of an incomplete mixture of the sewage laden waters of the Des Plaines river with the waters of the Kankakee. Prior to the opening of the drainage channel the Chicago sewage discharged into the Des Plaines river experienced no considerable dilution before getting the waters of the Kankakee, except when the Des Plaines itself was in flood. This, however, was rarely the case at times other than those of the usually short spring freshets. When the Kankakee was in flood, the dilution at this point was of course correspondingly great, as much as 50 to 1; the average dilution for the year being about ten to one, but ordinarily in the summer and autumn the dilution would probably rarely exceed two or three to one, and often fall far short of this. Since the opening of the drainage canal the flow in the lower Des Plaines is far more uniform and the average is just about equal to the average flow of the Kankakee, which is about 300,000 cubic feet per minute.

5377 Nitrogen as nitrates was present in greater proportion in the year 1900 than in the year 1899, or the average for the four years preceding the opening of the Chicago drainage canal was greater than the proportion contained during the year 1900.

5378 The nitrites in the waters of the Des Plaines river at Joliet have been considerably greater in proportion since

the opening of the Chicago main drainage channel than they were prior to that opening, and the same is true at Morris.

It is evident then, that such agencies as bring about the oxidation of the organic matters through ammonia to nitrites, and finally to nitrates, are fully as effective since the sewage has been more extensively diluted at and near Chicago. The fact that the nitrites are now found in greater quantity at Joliet and at Morris indicate that the nitrifying action going on in the river is more active at a point nearer to Chicago; that is, that the oxidizing influences at work upon the organic matters in the waters of these streams are more efficient now nearer to Chicago, this undoubtedly being one of the results of the greater dilution of the sewage with comparatively pure and oxygen saturated Lake Michigan water.

5379 Table of Averages No. 6 corresponds to tables 21, 22 and 23 heretofore placed in evidence, and is reproduced on page 5379 and represents the averages for the Fox river.

5380 The analyses show the changes which take place during the flow of 24 miles from Morris to Ottawa, without further dilution and without notable addition to impurities, but the mixing of the discharges from the Des Plaines and the Kankakee is not yet complete at this point, and some of the variations of the individual analyses are due to this cause. It is to be noted that at this point the nitrites are found in the waters of the Illinois river in greater proportions than at any other point along its course, which fact taken into consideration with the other indications of the analyses, shows that it is in this stretch of the river that the final oxidation processes which convert the organic matters of the sewage into innocuous mineral substances, the free ammonia, the nitrites and the nitrates and so on, are most active and effective.

5381 Defendant's Table of Averages No. 7 for the waters of the Illinois river at La Salle shows averages of results of

Vol 3

tables No. 24, 25, 26 and 27 heretofore introduced in evidence.

5382 Between Ottawa and La Salle the conditions in the river are such as favor the abundant growth of vegetation and the waters at this point consequently become charged with organic matters to a greater extent than at Ottawa. The nitrates also are found at this point in greater proportion than they are found at Ottawa, and they have not been very notably reduced in proportion by the dilution resulting from the discharge through the Chicago main drainage channel, a fact which is noted from comparison of the averages for the four years preceding, and those for the year following the opening of the drainage channel.

From Lockport to Ottawa the mixing of the waters seems to be at no point complete, and variations in the analyses due to this imperfect mixing are frequent, but a study of the conditions at La Salle including analyses of cross-section samples has shown that at this point the waters have ordinarily mingled completely. Just below the town of La Salle there occurs the final discharge from the Illinois and Michigan canal which carries most of the sewage of La Salle and the discharges of sewage and manufactering wastes from the town of Peru. It should be noted at several points between Joliet and La Salle there are minor discharges from the Illinois and Michigan canal into the Des Plaines river and the Illinois river, and that prior to the opening of the drainage channel the old canal, that is, the Illinois and Michigan canal, at times carried practically undiluted Chicago sewage throughout much of the sixty-six miles of its lower course. Indeed, in period of low water, the channel often carried the entire body of Chicago sewage past Joliet and discharged it at various points many miles below that at which it is now delivered into the river, thus carrying the pollution much farther down stream than the points at which it is now found.

5383 Since the opening of the main drainage channel the diluted sewage which enters the stream between Lockport

and Joliet is mainly carried by the Des Plaines and Illinois rivers, and the volume discharged from the canal at points below Joliet constitutes a much smaller proportion of the volume of the river. Moreover, the water of the channel is now in far better condition because of its great initial dilution at Joliet and the more thorough-going natural purification thereby occasioned.

5384 It is evident from the comparison of these averages that the proportions of organic matters contained in the waters of the Illinois river at La Salle have been very considerably reduced as a result of the greater dilution produced by the opening of the Chicago main drainage channel, that the proportions of nitrogen as nitrites is now less than one-half what it was before the opening of the drainage channel, while the proportions of nitrogen as nitrates are but slightly less than they were before that opening.

Table of Averages No. 8 shows average of results as indicated on tables No. 28 to 32 inclusive, heretofore introduced in evidence, as to the examination of the Illinois river at Averyville.

5385 Q. Now what significance do you attach to these tables and to the table of averages which you have just put in evidence?

A. The tables Nos. 28 to 32 inclusive contain the data of analyses of samples of water taken from the Illinois river at North Peoria or Averyville. That is beside the bridge at the Narrows, three miles above the Peoria Court House, a point where none of the sewage of Peoria finds its way into the waters of the stream.

The analyses were made upon samples which were collected regularly each week throughout the period in question beginning April 26, 1897, and ceasing December 26, 1901, except that during the first half of the year 1901 the collections were made but once a month, the averages however, for such years as are not covered by regular weekly samples have been made first for each month in the year, and the year's average made up from

the monthly average. In other cases the averages have been made straight from the various weekly samples.

Between La Salle and Averyville there is no considerable additional dilution of the waters of the stream and no great amount of impurities introduced except that discharged from the Illinois and Michigan canal just below La Salle, which discharge contains most of the sewage of La Salle, and in addition the discharge of the sewage and manufacturing wastes of Peru, which is just below La Salle.

5386 The study of the data of the analyses and particularly comparison with those for the other points along the river between Averyville and Lockport show unmistakably that a very great purification of the waters of the stream takes place as they flow along the 125 miles of its course between these two points. The seasonal variations in the water of the river at Averyville as may be seen by study of the detail analyses contained in tables 28 to 32 inclusive, are quite considerable, but the limits of variations are in most respects considerably less since the opening of the Chicago main drainage canal than they were formerly. The variations of the chlorine are shown diagramatically upon Plate VIII.

It is quite natural under the existing circumstances, that the proportions of chlorine should be smaller during the high water period, that is, in February, March and April, and that in

5386 the later season of the year, the warmer summer months when the flow is very much reduced, the contents of chlorine should be much greater than at other periods, and this plate too, shows in general the difference between the first six months and the second six months of the year, for formerly, that is particularly before the opening of the Chicago main drainage channel there was a much more considerable difference between high water conditions and low water conditions in the Illinois river with respect to the chlorine contained, as also with respect to the organic matters than is the case since the opening of the main drainage channel.

Plates IX and X show graphically the seasonal variations

in content of free ammonia. Plate IX having upon it the data for the weekly analyses represented by curves for the years 1897, 1898, 1899 and 1900, while upon Plate X the monthly averages, showing the proportions of nitrogen as free ammonia for the years 1897 to 1901 inclusive are represented.

The curves of both of these plates show the general variations in the content of nitrogen as free ammonia, as it varies with the seasons, the proportion being very great in the cold weather season, that is in January and February, and in general too, in November and December, while the proportions during the warmer seasons, that is the late spring, the summer and the early autumn seasons, are very much less than at other times during the year.

It is very noticeable that both before and since the opening of the Chicago main drainage channel the proportions of free ammonia are much greater in cold weather than at other seasons, and it is evident too, that the proportions of free ammonia content in the water of the Illinois river at Averyville are much less since the opening of the Chicago main drainage channel than they were before that time.

Plate XI of this series gives by means of curves the proportions of nitrogen as nitrites contained in the water of the Illinois river at Averyville, these being represented as monthly averages.

The curves of this plate show at a glance that the period when nitrites are most abundant in the Illinois river water at Averyville, is in general the summer time, or early autumn when the flow is at the minimum and the temperature at the
5387 maximum. The conditions with respect to nitrates being just the opposite to those referred to above, with respect to the nitrogen as free ammonia. It is evident from the figures in tables of analyses, and it is shown graphically upon the plate, that the proportions of nitrites since the opening of the drainage channel are in general less throughout the year than they were before the opening of the main drainage channel.

Comparison of the figures of table of averages No. 8, show

that as a result of the dilution effected by the opening of the Chicago main drainage channel, or at least subsequent to that opening, the proportions of the various significant constituents of the water of the Illinois river at Averyville are very greatly reduced.

The data throughout show this. The chlorine has been reduced from 20.2 the average for the three years prior to the opening of the drainage channel, to 17.5, the average for the two years subsequent to the opening. Similar reductions in the proportions of oxygen consumed both the total and that consumed by dissolved and by suspended matters, are evident. That the nitrogenous organic matters are very much reduced in
5388 proportion is evidenced at once by comparison of the relative quantities of nitrogen as albuminoid ammonia, and the total organic nitrogen for the two periods, the total organic nitrogen being on the average for the two years of 1900 and 1901 .742, while the average for the three years 1897 to 1899, is .98.

The total organic nitrogen in dissolved matters being .555 for the two years 1900 and 1901 as against .72 for the three years prior thereto. The nitrogen in suspended matters for the two years 1900 and 1901 being .187 as against .262 the average for the three preceding years.

The nitrogen as albuminoid ammonia, the total, was for the years 1900 and 1901 .286, while for the three years preceding the average was .466.

The albuminoid ammonia derived from dissolved substances being for the years 1900 and 1901 .212, while for the three years preceding, it was .336.

The albuminoid ammonia derived from suspended matters was on the average for the years 1900 and 1901 .076, and for the three preceding years the average was .13.

5388 The proportion of nitrogen as free ammonia for the years 1900 and 1901 was .643, while for the four preceding years the proportion was .909, and for the year 1899 the proportion was 1.025.

The proportion of nitrogen as free ammonia thus was less than two-thirds as much in the waters of the Illinois river at this point after the opening of the Chicago main drainage channel than it was prior thereto.

Comparison of the proportions of nitrites shows a very great decrease at this point since the opening of the drainage channel, the quantity being less one-half that formerly contained. Thus the proportions of nitrogen as nitrites on the average for the years 1900 was .079, for the year 1901, .081, and the average for the two years being .08.

The average proportion of nitrogen as nitrites for the year 1897 was .254; for the year 1898 .124; for the year 1899, 204; the average for the three years being .194, considerably more than twice the proportion found in the water at this point since the opening of the drainage canal.

That the reduction of these constituents is not wholly due to mere dilution, but that in part at least it is due to the greater proportional destruction of the organic matters discharged into the stream at Lockport and Joliet would seem to be evident from the fact that the nitrates are found in greater proportions in the water at this point now than they were before the opening of the drainage channel; the average proportion for the three years prior to the opening of the Chicago main drainage channel being 1.351 while the average for the two years subsequent to the opening of the channel was 1.46.

Comparison of the figures of table 8 for Averyville, with those of table 7 for LaSalle, show that there has been a very great decrease in the organic matters during the flow of 60 miles between these two points. The diminution is very considerable in each case, even including the nitrates, but the most significance attaches to the marked diminution in the proportions of nitrites and free ammonia and albuminoid ammonia, and total organic nitrogen. The proportions of nitrites have been reduced about fifty per cent., which would appear to indicate that the nitrification processes are approaching completion; this in

turn indicating that those organic substances which are
5389 easily susceptible to bacterial action have in great part already been consumed. In fact, it is highly probable that the refuse animal matters introduced in the sewage of Chicago have been completely destroyed, and that the organic matters which are contained in the river water at this point are derived from vegetable and not from animal sources.

In fact, vegetation of various forms, the plankton, and so on, is exceedingly abundant in the river between LaSalle and Averyville. The water of the river between these points and especially near Averyville may often be seen covered with floating masses of vegetation consisting largely of filamentis and other algae.

Comparison of the averages for Averyville with those for the tributary streams serves to show that the waters of the Illinois river at this point contain considerably less organic matters than are contained in the waters of its chief tributaries, which latter have never been in contact with Chicago sewage, although of course they receive some sewage from comparatively small towns. It is very evident of course that free ammonia and nitrites are still present in the waters of the Illinois river at this point in greater quantities than are contained in most of the tributary streams but the considerations detailed above and all available data show unmistakably that the character of the water in the streams at Averyville is now far better than it was before the Chicago sewage received its initial dilution at Chicago, and not at the junction of the Des Plaines and Kankakee rivers, sixty miles nearer to the point now under consideration.

5390 It is my opinion that the animal matters discharged by the two canals, the Chicago main drainage channel and the Illinois and Michigan canal, into the Des Plaines river in the vicinity of Lockport and Joliet, and discharged by the Des Plaines into the Illinois river about ten miles above Morris, have been entirely destroyed before the waters of the Illinois river reach Averyville, and the substances of said animal mat-

ters have been in part converted into mineral substances, and in part built up into the substance of living vegetation, this opinion being based upon my study of the waters of the streams in question, at the various points enumerated in my testimony in this case, and upon the evidence of the chemical analyses which have been introduced as part of my testimony.

Defendant's table of averages No. 9 conforms to tables No. 33, 34, 35 and 36, showing results of examinations of waters from the Illinois river at Havana and is reproduced on page 5391.

5391 The collections for Havana were made at a point about a mile and a half above the town, above the mouth of the Spoon river and the mouth of Quiver Lake, between Averyville and Havana. The sewage and manufacturing wastes are introduced into the river at Peoria and Pekin in quantities second only to those introduced through the Chicago main drainage channel and the Illinois and Michigan canal. These, however, consist very largely of refuse from stockyards, from cattle sheds; from some 40,000 to 50,000 cattle which are fed upon distillery slops.

5392 Prior to the opening of the Chicago drainage canal the condition of the river along this stretch of 45 miles was at many places during the summer time practically that of an immense septic tank. The offensive condition of which was striking throughout much of this stretch, but was greatest in the near vicinity of Peoria and Pekin.

The data of the detailed analyses which appear in the tables 33 to 36, inclusive, show the seasonable variations similar to those which were found at Averyville in comparison of the yearly averages which are brought together in table of averages No. 9, A. W. P., with those for Averyville which appear in table of averages No. 8, A. W. P., show that notwithstanding the introduction of an enormous amount of filth between Averyville and Havana, the putrefactive and other purifying processes going on in the waters of the stream have sufficiently reduced them to proportions of the various constituents so much that they were

but slightly different at Havana from what they were at Averyville, although an analysis of samples taken at Wesley just below Peoria and also at Pekin, show a notable increase in the content of organic matters at these two points, above the quantities found at Averyville and above those found at Havana, thirty miles below Pekin.

Comparison of the figures for the year 1900 with those of the years 1896 to 1899, inclusive, all of which appear in table of averages No. 9, shows the effect of the opening of the Chicago main drainage channel in reducing the proportions of the various constituents here considered. With the exception of the nitrates, the reduction of the various constituents is very considerable. The fact that the nitrates are not proportionally lowered seems to indicate that oxidation at this point is more complete since the opening of the sanitary canal than it was previously.

5393

Numerous determinations of dissolved oxygen in the waters of the Illinois river at Havana covering several years show that although at times the water is saturated in general, the content of dissolved oxygen is at this point considerably less than is required for saturation and at all times the dissolved oxygen diminished rapidly upon allowing samples to stand, as will be shown hereafter when a table upon that subject will be presented.

Table of averages No. 10 conforms to tables No. 37, 38, 39, 40, 41, 42 and 43, showing results of examination of Illinois river water at Kampsville and is reproduced on page 5393. The comparison of the data of the two three-year periods affords an excellent opportunity of judging of the effects of dilution occasioned by the opening of the Chicago main drainage channel upon the character of the waters of the Illinois river as they are about to flow into the Mississippi river at Grafton thirty miles below Kampsville.

5194

Plates Nos. XII and XIII show that in the usual high water period, that is, the first half of the year, chlorine is contained in the water of the Illinois river at this point in just as consider-

able proportions as before the opening of the Chicago main drainage channel but that in the latter part of the year which was formerly a period of extremely low water, the content of chlorine is now found to be considerably less than formerly, the seasoned variations as revealed by regular weekly analyses being represented upon plate XII by lines for the years 1897 to 1900, inclusive, and upon plate XIII, the averages for each month being represented for the years 1897 to 1901, inclusive.

Plate No. XIV represents variations in the proportions of nitrogen as free ammonia, and shows the great difference in respect to proportional content of free ammonia between cold weather and warm weather conditions.

Plate XV represents the seasonal variations in the proportions of nitrogen as nitrites and shows that the nitrites are not contained in the river at this point in so great quantity as they were previous to the opening of the Chicago main drainage channel, but that they follow the same general course of seasonal variations as formerly; that is, they are least in cold weather and greatest in hot weather.

Plate XVI shows by means of monthly averages, the 5395 proportions of total organic nitrogen both dissolved and total and the seasonal variations which took place with respect to the content of nitrogenous organic matters.

Comparison of the averages for the three years 1897, 1898 and 1899 with each other shows no very great variation in the organic matters, though the oxygen consumed, the free ammonia and the total organic nitrogen increase somewhat from year to year, while the nitrites and the nitrates decrease.

Comparison of the averages for 1900 with those for 1899 show that immediately after the opening of the Chicago drainage channel there was a notable decrease in the proportions of the various constituents with the single exception of nitrates. The decided increase of which, taken into consideration with the 25 per cent. decrease in the proportion of nitrogen as albuminoid ammonia indicates that under the new conditions the oxidation of the organic matters is more complete as the waters of the

Illinois flow along its course from the point of initial pollution by Chicago sewage to Kampsville where they are about to discharge into the Mississippi river, that is, within 30 miles of the point at which that discharge into the Mississippi occurs.

The averages for 1901 correspond fairly well with those for 1900 except that the total organic nitrogen appears decidedly higher, but this is due to the fact that the data for this constituent cover but the first nine months of the year as a press of overwork made it necessary to discontinue the determination of total organic nitrogen at this time. The higher free ammonia in 1902 over the proportions contained in 1901 and 1900 is chiefly due to the fact that in January and February, when the cold weather conditions are usually accompanied by high free ammonia in the Illinois river, the stage of water in the Illinois was remarkably low and the concentration correspondingly great.

Comparison of the averages for the two 3-year periods makes evident the great diminution in the proportions of
5396 the various constituents except free ammonia which is .393 parts per million in the latter period as against .371 parts per million in the earlier period and the nitrates, which have very considerably increased.

Plate XVII exhibits graphically by means of columns some of the facts shown in table of averages No. 10 and facilitates the comparisons between the averages for the separate years.

Stipulation that samples of water taken at various places have been taken in the manner described by Prof. Long.
5397 "Department of Chemistry, University of Illinois, Defendant's Exhibit B for identification, A. W. P." offered in evidence, being a table representing the dissolved oxygen in the Illinois river at Havana.

JUDGE SPRINGER: Professor, will you proceed with your explanation of the chemical examinations of water at Kampsville, and table of averages based thereon?

A. With respect to the higher proportion of free ammonia in the water during the second period of three years, that is the

period subsequent to the opening of the Chicago drainage channel, it is evident that this is mainly due to the unusually high proportion of free ammonia contained in the water of the stream at this point during the year 1902. The proportions of free ammonia during the months of January and February, 1902

5398 were particularly excessive, the weather being at this time very cold and the volume of water in the stream being unusually small, even for this season of the year, and the proportion, that is the average proportion for the year is at a higher point for the reason that the year 1902 was on the whole, an unusually high water year. The water was higher particularly during the ten months following February than it had been at any time during the six years here under consideration. Plates XVIII and XIX representing the discharge curves of the Illinois river from Kampsville dam, reproduced on pages 5399 and 5400.

5403 Tables No. 1 to 7, A. W. P entitled, "Tables of Discharges of water over the Kampsville dam for years 1896 to 1902 inclusive," offered in evidence and reproduced on pages 5404 to 5424 inclusive.

5425 These tables were the basis upon which the charts or tables were made.

5426 Table of Averages No. 11 shows the averages of results shown in tables No. 43, 44, 45 and 46 heretofore introduced in evidence, being an examination of the waters of the Illinois river and the Mississippi river at Grafton.

5427 Comparison of the data of the analyses show seasonal variations of considerable magnitude in the waters of the Illinois river at Grafton, the most important of which are the albuminoid ammonia and the total organic nitrogen are shown in Plates XX and XXI, which are reproduced on pages 5428 and 5429.

5431 It is obvious from inspection of the curves of Plate XX and is shown definitely by the figures of the tables to which the curves give expression, that during the times when the albuminoid nitrogen and the total organic nitrogen are par-

ticularly excessive in quantity, in the water of the Illinois river at this point, it is mainly in suspended matters and not in the substances which are in solution, while during the periods of less flow, the organic nitrogen and the albuminoid nitrogen are general chiefly in substances which are in solution in the water, and not in the matters which are merely suspended.

Upon Plate XXI, there are shown similar lines for the year 1900. The lines follow much the same general course throughout the year. They represent the various analyses, the details of which are given in table No. 44 of this series.

5432 Study of the figures of the table and inspection of the curves of the plate show that during the year 1900 the variations in the proportions of nitrogen as albuminoid ammonia and of total organic nitrogen follow much the same curves as during the preceding year 1899, thus there was during the early part of January a decrease in the proportions which was followed in the latter part of January by an increase, to be again followed by a decrease to the 31st of January, which decrease in the case of the total organic nitrogen continued to the 7th of February, after which there was an enormous increase to the 14th of February, which again was followed by a considerable decrease to the 21st of February, which however was followed by another though less considerable increase to the 28th of February, and on to the 7th of March, after which again a decrease occurred, followed by an increase to the 14th, after which the decrease which occurred again was more considerable, and from that time on to the end of the year the proportions never rose to such considerable amounts as during February and March, and the variations were much less considerable from week to week.

Again with respect to the curves of this plate it may be stated that during the time when the proportions of total organic nitrogen and of total albuminoid nitrogen are at the maximum, or at the higher points, it is mainly due to the excessive proportion of the nitrogen contained in suspended matters, that is the greater proportion of the total organic nitro-

gen, as also of the nitrogen as albuminoid ammonia is at such times contained in matters which are in suspension in the water and not in the substances which are in solution.

Comparison of the averages for the different years which appear in the table of averages No. 11, above referred to shows that subsequent to the opening of the Chicago main drainage channel, the proportions of the various significant constituents of the water of the Illinois river at Grafton, were in most cases considerably reduced.

5434 The samples of water from the Mississippi river at Grafton were taken at mid-stream, at a point about two miles above Grafton, and above that at which any discharge from the Illinois river enters the Mississippi. The detail analyses which appear in tables 47 to 50 inclusive, show that seasonal variations in the constituents of the waters of the Mississippi river are in many respects more frequent and more considerable than the seasonal variations in the waters of the Illinois. This is especially true of the albuminoid ammonia and the total organic nitrogen as is evident upon consideration of the features of Plates XXII and XXIII, which are reproduced on pages 5435-6.

5440 Upon Plate XXIV, reproduced on page 5439, there appears lines which represent the proportions of chlorine contained in the waters of the Illinois river near the mouth at Grafton, and similar lines representing proportions of chlorine contained in the waters of the Mississippi at a point just above Grafton, the curves in this plate representing the monthly averages for the chlorine and covering the years 1899, 1900 and 1901. With respect to the lines representing the chlorine in the waters of the Illinois river, it is evident that during most of the year the proportions are far in excess of the proportions of chlorine contained in the Mississippi river, but that there is a great variation or difference between the conditions in this, with respect to the proportion of chlorine in the high water period, which is generally March and April, and the low water period which generally is the latter part of the year, but which frequently

includes also the first two months of the year, that is, January and February.

Comparison of these data of table of averages No. 11, which represent the averages for the Mississippi river water just above the mouth of the Illinois for the years 1899 to 1902 inclusive, shows somewhat notable variations from year to year, but a comparison of the averages for the Mississippi with those for the Illinois shows that organic matters as represented by the oxygen consumed were, in each of the four years contained in the waters of the Mississippi in considerably greater proportions than in the waters of the Illinois in 1899, and were nearly 50 per cent greater than the average for the three years after the opening of the Chicago main drainage channel. Thus, the oxygen consumed by the waters of the Mississippi river at Grafton for the year 1899, was 15.2; for the year 1900, 16.4; for the year 1901, 14.1; for the year 1902, 14.7; the average for the four years being 15.1 as against the average for the Illinois river in 1899 of 12.6. The average for the three years, 1900, 1901 and 1902, being 10.

The proportions of oxygen consumed by matters contained in solution in the water of the Mississippi river at this point were for 1899, 9.8; 1900, 10.6; 1901, 10.6; 1902, 9.3; the average for the four years being 10 parts per million as against 8.3 for the Illinois in 1899, and an average of 7.4 for the three years subsequent to the opening of the Chicago main drainage channel.

5441 The oxygen consumed by suspended matters in the waters of the Mississippi were in 1899, 5.4; in 1900, 5.8; in 1901, 3.5; in 1902, 4.5; the average for the four years being 4.8; the proportion in excess of that required by suspended matters in the water of the Illinois river during 1899, which was 4.3, and also considerably greater than the average for the Illinois river for the three years, 1900, 1901 and 1902, the figures for that year being 3.3.

The free ammonia contained in the waters of the Mississippi river at Grafton, reached the proportion of .077 for the

year 1899, the average for the year 1900 being .133; for the year 1901, .182; for the year 1902, .095; the average for the four years being .116, as against the average for the Illinois river in 1899 of .313, and the average for the three years, 1900 to 1902, being .332.

The albuminoid ammonia in the waters of the Mississippi river for the year 1899 were on the average .508, the average for 1900 being .448; for 1901, .403; for 1902, 464, the average for the four years being .455, a quantity slightly less than that contained in the Illinois river water in 1899, which latter was .479, but considerably in excess of the proportions found on the average in the Illinois river water for the three years, 1900, 1901 and 1902, which average was .37.

Albuminoid ammonia derived from dissolved substances in the Mississippi river at Grafton for 1899 was .217; 1909, .222; 1901, .202; 1902, .189; the average for the four years was .207; the average for the water of the Illinois river for 1899, was .247, and for the three years subsequent thereto, that is, 1900, 1901 and 1902, it was .22; the proportions in the Illinois river being slightly greater than the proportions in the Mississippi.

5442 The albuminoid ammonia derived from suspended matters was for the Mississippi river in 1899, .291; 1900, .226; 1901, .201; 1902, .275; the average for the four years being .248, as against .232 in the Illinois river in 1899, and .149 the average for the Illinois river for the three years 1900 to 1902 inclusive.

Total organic nitrogen in the waters of the Mississippi at Grafton were for 1899, 1.168; for 1900, 1.03; and .969 for such portion of 1901 as is covered by the data in table 49 of this series. The average for these three years or such portion thereof as the data pertains to being 1.0155 as against the average for the Illinois river in 1899 of 1.148, an average for two years, 1900 and 1901, of .957.

Organic nitrogen derived from dissolved substances in the Mississippi river at Grafton for 1899, .485; 1900, 4.76; 1901-.431;

the average of these being .464, as against .596 for the Illinois river in 1899, and .512, the average for the Illinois river for the years 1900 and 1901.

Total organic nitrogen derived from suspended matters for the Mississippi river water at Grafton for 1899 is .683; for 1900 .555; 1901, .538; the average being .592, as against .552 in the Illinois river water for 1899, an average of .444 for the Illinois river water for 1900 and 1901.

Nitrogen as nitrites in the water of the Mississippi at Grafton were .012, for 1899; and .007 in 1900; and .006 in 1901, and .01 for 1902, the average for the four years being .009, as against .045 in the Illinois river water in 1899, an average of .03 for the three years, 1900, 1901 and 1902.

Nitrogen as nitrates in the Mississippi river water at Grafton was on the average .34 parts per million for the year 1899; for the year 1900 the average was .471; 1901 the average was .314; 1902 the average was .469; the general average for the four years being .405 as against the average of 1.063 in the Illinois river water in 1899, and 1.237, the average in the Illinois river water for the three years, 1900, 1901 and 1902. The data of the tables show in general that the proportions of nitrogenous organic matters as represented by albuminoid ammonia and total organic nitrogen were notably higher in the Mississippi river than in the Illinois river, although in the year 1901 they were slightly higher in the latter stream. On the other hand the oxidation products of nitrogenous organic matters represented by free ammonia, the nitrites and the nitrates, were present in the waters of the Illinois in proportions which are two to three times those contained in the waters of the Mississippi, and the total nitrogen, that is, the sum of the total organic nitrogen, the nitrogen as free ammonia and the nitrogen as nitrites and nitrates was 2.546 parts per million in the waters of the Illinois as against 1.585 in the waters of the Mississippi. The 5443 preponderance of nitrogen in the waters of the Illinois over the proportions contained in the waters of the Mississippi is doubtless due to the fact that the watershed of the

former is more extensively and more intensively cultivated than that of the latter, and that the industrial wastes which are discharged into the Illinois are more highly nitrogenous in character than are many of those which find their way into the Mississippi. For example, the refuse matters discharged into the Illinois river at Peoria and Pekin consist largely of the highly nitrogenous wastes from glucose factories and those resulting from the feeding of cattle upon distillery slops, while the organic matters contained in the waters of the upper Mississippi are derived largely from the wastes of the lumber industries and these are not nearly so highly nitrogenous in character. Both streams of course, receive in the aggregate enormous quantities of sewage.

Determinations of dissolved oxygen in the waters of the Illinois and Mississippi rivers at Grafton, show that in general of the waters of the Illinois contain practically the same proportions of oxygen in solution as the Mississippi although the stability of the organic matters as measured by the partial disappearance of the dissolved oxygen when the samples are allowed to stand in the dark for 24 hours, is somewhat greater for the Mississippi than for the Illinois.

The data of these various determinations of dissolved oxygen have been heretofore introduced as evidence and need not be brought in here in detail, but in order to explain graphically the proportions of dissolved oxygen in these waters I refer now to Plate No. XXV, A. W. P., which has already been offered in evidence and is reproduced on page 5444.

5445 I have prepared no tables of averages with respect to tables No. 51 to 62 inclusive, except the averages which appear at the bottom of each of the tables.

With respect to the data included in the tables 51 to 62 inclusive, I may say that for several years samples of water were collected from the Illinois river at the intake of the old Alton city waterworks, and also a few samples were collected at mid-stream, but that in the fall of 1898, arrangements were made for the collection of a series of samples at a point opposite

the new waterworks nearly a mile above the town. At this place five samples were collected at five different points across the stream for the purpose of determining the differences in composition due to the incomplete mingling of the waters of the Illinois river with those of the Mississippi river. The point at which these samples were taken was 16 to 17 miles below the mouth of the Illinois river at Grafton and six or seven miles above the mouth of the Missouri river or fifteen or sixteen miles above the intake of the St. Louis waterworks at the Chain of Rocks.

Consideration of the data of the twelve tables shows how incomplete is the mixing of the waters of the Illinois with the waters of the Mississippi, the facts being brought out especially by comparison of the proportions of chlorine contained in the waters of the Illinois river and the Mississippi river above Grafton with those found at different points in the cross-section of the stream at Alton. In explanation I will refer
5446 to Plate No. XXVI which has heretofore been offered in evidence. This Plate No. XXVI gives comparative curves representing the results of chlorine determinations in the regular weekly samples collected throughout the years 1899 and 1900, the data appearing in detail in the tables 53 and 62 inclusive. Several times in January and February when because of stationary ice or floating ice it was impracticable for the collector to reach the proper points, collections were made at the ferry crossing opposite the town, nearly a mile below the point at which collections were at other times made, so that the data for portions of these two months for both years, show the proportions of chlorine, which are not truly representative for the Missouri side of the stream, because the collector who started from the Illinois side couldn't get far enough out toward the Missouri shore.

Plate No. XXVI is reproduced on page 5447.

In the latter part of the year 1900, as it was found necessary to contract the amount of work being done upon these waters

the collection at one-fourth distance from the Missouri
5448 shore and at one-fourth distance from the Illinois shore, were discontinued and only three taken at the cross-section points, namely: one near to the Illinois shore; one near to the Missouri shore, and one at a point midway between the two banks.

Comparison of the lines representing the proportions of chlorine contained in the water of the Mississippi at Grafton and with the lines representing the proportions of the chlorine contained in the water of the Illinois at Grafton and with those representing the proportions of chlorine found in the incomplete mixture of Illinois river and Mississippi river waters at the different points at Alton, show that the water toward the Illinois shore was much more like the water of the Illinois river than it was like that of the Mississippi river above Grafton, with respect to the content of chlorine, and that the water of the Mississippi at Alton towards the Missouri shore was very much like that of the Mississippi above Grafton and very much more like that of the Mississippi above Grafton than like that of the Illinois.

5449 Plate XXVII represents a cross-section of the Mississippi river at Alton and shows seasonal and other variations of chlorine at five different points across the stream in 1899 and is reproduced on page 5449.

5450 Plate XXVIII represents the same conditions for the same place for the year 1900 and is reproduced on page 5450.

5453 Plate XXIX reproduced on page 5452 represents the proportions of Illinois river water and Mississippi river water which constitute the mixture at different points across the stream at Alton, that is opposite the pumping station of the Alton city water works.

The quantities of water, that is the proportional quantities of Illinois river water and Mississippi river water have been calculated from the average content of chlorine for the year for each one of the five points in the cross section. They show

that comparatively little of the water of the Illinois river reaches the Missouri side of the Mississippi at this point. For the year 1899 2.4 per cent of the water near the Missouri shore came from the Illinois river; the other 97.6 per cent consisting of water from the upper Mississippi at the point one-fourth the distance from the Missouri shore, the Illinois river water amounted to 4.8 per cent., while the Mississippi river water was 95.2 per cent of the mixture; at the mid-stream, that is a point midway between the two banks the proportion of Illinois river water was 11.3 per cent; that of the Mississippi, that is the upper Mississippi river water was 88.7 per cent. At a point one-fourth distance from the Illinois shore, the Illinois river water amounted to 23.5 per cent., while the Mississippi river water amounted to 76.5 per cent. Near the Illinois shore the Illinois river water preponderated, amounting to 30 per cent. of the water passing down at that point; the Mississippi water constituting 62 per cent of the mixture.

For the year 1900, similar facts appear, except that there was a little more of the Illinois river water towards the Missouri shore, the percentage being 4 per cent Illinois river water near the Missouri shore; 96 per cent Upper Mississippi river water.

At one-fourth distance from the Missouri shore the Illinois river water constituted 10 per cent of the mixture, while the Mississippi river water constituted 90 per cent. At mid-stream there was 13 per cent of water from the Illinois river and 87 per cent of water from the upper Mississippi.

At one-fourth distance from the Illinois shore the mixture consisted of 40 per cent. Illinois river water and 60 per cent. water from the upper Mississippi; while close to the Illinois shore, the mixture contained 46 per cent of Illinois river water and 54 per cent of water from the upper Mississippi.

It is evident from the data of the tables 51 to 62 inclusive, and is expressed graphically by the figures and the lines of this plate, that the Illinois river water does not mix perfectly with

the Mississippi river water, but passes down mainly to-
5454 ward the Illinois shore or along side the Illinois shore on its way down stream in the bed of the Mississippi river.

From certain analyses of samples of water taken in the Mississippi river about half a mile above the mouth of the Missouri river, it is my opinion that the mixing of the water of the Illinois with the water of the Mississippi is by no means complete by the time these bodies of water reach the mouth of the Missouri.

In my opinion there is no thoroughly satisfactory basis for a calculation of the relative proportions of Illinois river water, Mississippi river water and of Missouri river water, in the mixture which passes the intake tower of the St. Louis waterworks, but for such calculations the chlorine content would in all cases be the most satisfactory basis because the chlorine is not a variable constituent, or rather does not vary from causes which bring about variations of all other constituents which it is customary to determine in sanitary water analysis.

Q. Would it be practicable to calculate the mixing of the waters of the three rivers at the chain of rocks from the proportions of free ammonia?

5455 A. It would not, because free ammonia changes, sometimes rapidly, sometimes slowly, but does change as a result of decomposition of organic matters contained in the water, in a way totally different from chlorine and it could not be assumed with good reason that a quantity of free ammonia found at one point or at one time would not change from processes going on within the water. On the other hand, chlorine does not change from any processes going on within the water itself, but only through the addition of more chlorine by the introduction of liquids or substances foreign to the water itself, or by concentration due to evaporation of the water containing the chlorine.

Q. Would it be practicable to calculate the mixing of the

waters of these three rivers from the proportions of nitrites?

A. It would not for reasons similar to those just stated with reference to the ammonia. The variability of the proportions of nitrites standing in the way of the nitrites constituting a reasonably safe basis for calculation of the quantities of the water, and the mixing of waters containing originally different proportions of nitrites.

Q. Would it be practicable then to calculate the mixing of the waters of these three rivers from the proportions of total solids?

A. It might be; in case the proportions of total solids were sufficiently different in the three streams which were coming together, but even then there would be very great difficulties in the way of making a reasonable approximate calculation or a reasonable approximation of the true proportions, for the reason that the total solids include matters which are in suspension, and which by reason of variations in velocity of the stream, variations in the character of the material lying in the bottom of the stream and constituting the banks of the stream, which cause variations in the proportions of suspended matters even within short distances.

Q. What reliability could be placed upon a calculation as to the mixing of the waters of these three rivers from the proportions of suspended matters?

A. That would be unsatisfactory for the reason just stated in referring to the possibility of calculating the mixing
5456 from the total solids, which total solids of course include the suspended matters. The different velocities at different times in the year and at different points even within short distances of each other, and the different character of the material with which the water is in contact, bring about in many cases a deposition of much of the suspended matters, forming as is well known, sand-bars and other deposits in the stream, and on the other hand, where the character of the banks or of deposits in the bed of the stream are such that they can be easily removed by water, oftentimes the water picks up and

holds in suspension considerable quantities of foreign matters which it may derive not from tributaries at some distance, but from localities and deposits quite near to the point at which determinations are made. That is to say, there is no certainty and in this particular case there would be no certainty that the quantities of suspended matters found in the waters of the Illinois at Grafton would proceed down in the Mississippi river to the St. Louis water works. There is no certainty that the quantities of suspended matters contained in the waters of the Mississippi above the mouth of the Illinois would remain in those waters until such time as this body of water reaches the intake of the St. Louis waterworks, and there is no certainty that such suspended matters as are contained in the waters of the Missouri river above its junction with the Mississippi remain in that water until such time as it reaches the intake tower of the St. Louis water works; for these reasons: Calculations based upon the suspended solids and upon the total solids which include suspended solids, have no sound basis in fact, and on the other hand, at times the body of water passing down the bed of the Mississippi above the mouth of the Missouri may between the mouth of the Illinois and the mouth of the Missouri pick up and hold in suspension matters which would then be in excess of the quantities found in the waters of the Illinois and of the Mississippi at and above Grafton, and likewise the mixture of the three bodies of water between the mouth of the Missouri river and the intake tower of the St. Louis waterworks, may in this stretch of six or seven miles,—perhaps eight or nine miles, pick up from the sand-bars and the banks of the river, suspended matters which were not contained at this time,
5457 at least, in the waters of either the Missouri or the Illinois or the Mississippi.

Hence, in my opinion, it is totally impracticable to calculate the relative proportions of water from these sources contained in the mixture passing down the Mississippi river beside the intake tower of the St. Louis waterworks, though by general study of all these constituents of the water, it is practicable to

get a general idea as to the relative quantities constituting the mixture at this point, that is to say, a rough general approximation may at times be arrived at by consideration of all these constituents, as the basis for a calculation, but only a rough general approximation, can in my opinion be arrived at from these considerations.

5458 The seasonal variations of free ammonia and also the cross section variations of free ammonia at Alton are shown in part upon plate XXX, which is reproduced on page 5459.

It is to be noted that during much of the year there is little difference between the proportions of free ammonia found at the different points, and also between the proportions found in the Illinois, and those in the Mississippi, and that at times more free ammonia is found in the waters of the Mississippi river than in the waters of the Illinois river.

Before leaving the discussion of the Mississippi river water at Alton I refer to plate No. XXXI, which has heretofore been offered in evidence and which gives by curves the stages of water in the river at this point for the years 1899 and 1900; and is reproduced on page 5461.

5462 I have prepared averages which appear at the bottom of each of the tables numbered 63, 64, 65 and 66, but none other.

With respect to these, I have to say that I have not got in print all of the set, but the numbers which are mentioned by counsel are here in print, but in addition to these there are three other tables which were offered in manuscript when the entire series of plates was introduced, and which are refered to at this point, together with the three mentioned by counsel.

A. I have those manuscript tables with me and they have already been put into the record, and are numbered 68, 69 and 70.

No. 67 appears in the original description of these tables, but I find that through my mistake that number was given to table 66, thus making two numbers for one and the same table,

so that we may, to straighten the matter out, designate this particular table as 66 and 67.

The samples of water, analyses of which appear in these tables, were collected from the Mississippi river at Quincy at a point near the end of the intake conduit of the Quincy waterworks, which is at a point above that at which any discharge of sewage from Quincy enters the river.

Before referring to the data of the analyses I will refer to plate No. XXXII, heretofore introduced in evidence, and upon which there appear curves representing the stages of water in the Mississippi river at Quincy during the years 1899 and 1900, which plate XXXII is reproduced on page 5463.

5464 A study of the data of analyses shows that the seasonal variations in the proportions of the different constituents of the water of the Upper Mississippi river are quite as frequent and fully as considerable as are the variations of these constituents in the waters of the Illinois river.

A portion of the data of table 63, namely all the data of that table which represent the proportions of chlorine the proportions of nitrogen as nitrites, the proportions of nitrogen as free ammonia, and the proportions of nitrogen as albuminoid ammonia, both the total and that derived from dissolved substances, and also the stages of water in the Mississippi at this point for the year 1897, are represented by curves upon plate XXXIII, which has heretofore been introduced in evidence, and which is reproduced on page 5465.

5466 Consideration of the lines representing the chemical constituents, and a comparison with the line representing the stages of water in the river, show that when there is a rise in the stage of water there is usually also a rise in the proportions of nitrogen as albuminoid ammonia; in the proportions of nitrogen as free ammonia and in the proportions of nitrogen as nitrites, and it is apparent from the lines in this plate which merely represent the figures of the actual analyses a record which is made in table 63 of this series, that the proportions of these significant constituents contained in the water during the

early spring, that is in March and in April, are very much greater than later in the year.

With respect to the data of table No. 64, in which there is given the results of analyses of samples of water taken from the Mississippi river at Quincy during the year 1898, regular weekly collections throughout the year, I refer to Plate XXXIV which is reproduced on page 5467.

5468 With regard to Plate No. XXXIV. It may be noted that in January and February of this year the proportions of nitrogen as free ammonia and of nitrogen as nitrites was much more considerable that at any other time during the year, while the proportions of nitrogen as albuminoid ammonia were greatest during the latter part of the month of March and at a time at about the middle of May. It will be noticed from both of these plates that the variations in the proportions of chlorine are never so considerate in the waters of the Mississippi as they are in the waters of the Illinois.

Comparison of the data for the Mississippi river at Quincy with those for the same stream at Grafton show substantially a similarity of the water at these two points, more than 100 miles apart, both as to the proportions of the different constituents and the variations of the same.

5469 In the table of averages No. 12, I have the averages of the data which appear in tables 71, 72 and 73 and also averages of analyses of waters of the Kankakee river collected at Wilmington during the year 1896, the data for which appear in my preliminary report which has been heretofore presented as defendants' Exhibit A for identification.

With respect to the data of these analyses I would say that the samples of water were collected at Wilmington a point ten or twelve miles from the mouth of the Kankakee river, and that the data of the analyses may be regarded as fairly representing the condition of the water of the Kankakee river as it is about to unite with the water of the Des Plaines river. Until the

Chicago main drainage channel was opened, the sewage
5470 discharged through the Illinois and Michigan canal met with its first notable dilution, usually only upon mixing with the waters of the Kankakee for although at times the flood flow in the Des Plaines would for a few days equal or even exceed the main flow in the Kankakee, that is, would amount to 300,000 to 400,000 cubic feet per minute, and at times even amount to twice this quantity, and would dilute the waters discharged from the Illinois and Michigan canal eight to ten and even sixteen to twenty times, yet the mean flow of the Des Plaines for the year is but one-fifteenth to one-tenth that of the latter stream, and the ordinary low water flow is proportionally even less.

Inspection of the figures of the detailed analyses show that there are notable variations in the composition of the waters of the Kankakee during the year. In general the variations are greatest in the spring of the year when freshets bring down such suspended matters, both mineral and chemical, but it will be noticed that there is a considerable diminution in the proportions of nitrates during the warm summer months; this diminution being in part the result of the growth of vegetation in the flowing waters of the stream; in part the result of the simulation of nitrates by the vegetation of the head waters in the Kankakee marshes, which during this portion of the year constitute the chief source of supply. The higher nitrates during the high water season are in part due also to the leeching of nitrates from the soil by the run-off, and the discharges from tile drains, both of which occur chiefly during the seasons of lower temperature and greater precipitation, which are consequently of course the seasons of high water.

With respect to these variations in the waters of the Kankakee I refer to Plate No. XXXV heretofore offered in evidence, but which has not been made up into a plate and printed, and I have but this one plate. The plate will be made and copies will be introduced. This plate is as follows:

(Copy not subsequently furnished, F. S. B., Com'r.)

5472 Table of averages No. 6 which also contains similar averages for the waters of the Illinois river at Ottawa, contains the averages for the Fox river at Ottawa, indicated on tables 74, 75, 76 and 77.

The Fox river is the largest tributary of the upper Illinois proper and next to that of the Kankakee its discharge is the most important diluting factor of the upper Illinois. Its discharge is more uniform in volume than that of the Des Plaines river and is greater in proportion to its water-shed area. The samples for analyses were collected above the town of Ottawa, and above the aqueduct which carries the water of the Illinois and Michigan canal across the stream, the season being that this aqueduct leaks and discharges water from the Illinois and Michigan canal into the Fox river at a point a short distance within its mouth.

The waters of the Fox are rather highly charged with organic mtaters which are mainly derived from the vegetation which is abundant in this stream, particularly in the marshes and shallow lakes which constitute the chief source of its head water supply. The stream receives the sewage and manufacturing wastes of a number of towns, of which Elgin, with a population of 22,433, and Aurora, with a population of 24,147, are the largest. Between these two towns is the town of Geneva, where there is a large glucose works, and in which 40,000 carloads of corn are used annually, the wastes from which—probably at least 150 tons of highly nitrogenous organic refuse daily, are discharged into the river. Below Aurora, comparatively little sewage and wastes enter the stream and there is considerable opportunity in the flow of 50 miles, between Aurora and the mouth, for the natural purifying processes to exert their influence in bettering the condition of the water. The averages which

5473 appear in table 6, contain the data of tables 74, 75, 76 and 77 in the form of general averages, and also an average for the entire three years represented, that is the years 1898, 1899 and 1900.

I was informed by an individual connected with the management of the concern in question referred to, who first told me personally that about 40,000 car-loads of corn were used annually there, and that the refuse was discharged into the river, and he subsequently confirmed his information in Geneva and wrote me to the same effect. I have further been informed by the president of the Fish Commission of the State of Illinois that such quantities of corn are used in the works at Geneva, and that the refuse is discharged into the Fox river and that it kills the fish in the Fox river.

3473 There are averages at the bottom of the tables numbered 78, 79 and 80, the latter of which appears only in manuscript and covers a portion of the year 1899, extending from January 3d to May 30th, this latter, that is table 80, has not been incorporated in the tables of averages No. 14, but there appear in that table in addition to the averages for the Spoon river for the years 1897 and 1898, also the average for the year 1896, the detail data of which appear in my preliminary report heretofore offered for identification as Defendants' Exhibit A.

Collections were made in the Spoon river at a point within about a half a mile of the mouth. Spoon river drains a watershed area of about 1870 square miles, but as there are no very considerable towns situated upon the stream of its watershed, it receives but little sewage and may be regarded as one of the least polluted of the natural streams of the State.

Q. Did you make any chemical examinations of the waters taken from the Big Vermilion river, which is one of the tributaries of the Illinois river?

A. I did. Most of these examinations however, have already been reported in my testimony with reference to the streams examination report. The table of averages No. 13 A. W. P. contain the averages for the years 1899 and 1900, details of which are given in the set of tables 1 to 80 inclusive referred to above as being testified to as part of the streams examination report, and in addition, there is a set of averages for the year 1896, which have been taken from the preliminary report here-

tofore offered for identification and referred to as defendants' exhibit A.

5476 Table of Averages No. 13 of waters taken from the Big Vermilion water at La Salle, and table No. 14 of waters from the Spoon river at Havana, reproduced on page 5476. The Big Vermilion is a most important tributary beteen Ottawa and Peoria; the discharge varies between wide limits, but it is an important factor as a diluting agent, only during the freshet season. In the drier season its flow is practically nothing but sewage, derived mainly from the towns of Pontiac and Streator, and from the drainage of factories and mines upon its banks; the stream is used as a source of water supply for the towns of Pontiac and Streator, and during much of the year the

5477 entire flow of the stream above these towns is used for water supply, and then is discharged again into the stream as sewage below the respective towns. The samples for analyses were collected about a half a mile within the mouth of the stream, the mouth being about three miles above the wagon bridge.

A. Comparison of the detailed data of the analyses of the water of the Illinois at Averyville and at Grafton, with the data of the analyses of the waters of the tributary streams, shows that the latter are subject to seasonal variations which in most respects are as great as are those of the Illinois. Comparison of the yearly averages which are given in defendants' tables of averages No. 15, A. W. P., shows that the proportions of organic matters as represented by oxygen consumed, albuminoid ammonia and total organic nitrogen are even more considerable in the waters of the larger tributaries than in the waters of the Illinois at Grafton, and the general averages for the six tributaries examined are substantially equal to the averages for the Illinois for 1900, 1901 and 1902.

5478 I should have explained before, that in the tables of averages, there is also given averages of analyses of samples collected from the Sangamon river at Chandlersville, details of which have been given in the set of tables 1 to 6 inclusive, offer-

ed in the report of Streams Examination for the Sanitary District.

In the table of averages it appears that the free ammonia and nitrites however, are in general more abundant in the waters of the Illinois river than they are in the tributary streams although three of the latter carry practically as much or more in nitrates as does the Illinois, thus, the proportions of nitrites contained in the water of the Illinois at Grafton during the years 1900 to 1902 being .03 parts per million; the average for the water of the Big Vermilion during the years 1896, 1899 and 1900 was .025, but little less and during the years 1896, 1897 and 1898, the waters of the Spoon river contain nitrogen as nitrites in the proportion of .041 parts per million, while the waters of the Sangamon contained on the average for the years 1890 and 1900, nitrogen as nitrites in the proportion of .032.

A portion of the data included in this table of averages No. 15 A. W. P., have been used in the preparation of Plate No. XXXVI, which is the duplicate of the one introduced in an earlier report, and which itself has been introduced in my testimony. The plate represents by means of columns the
5479 proportions, or the various constituents as chlorine, oxygen consumed, nitrogen as free ammonia, and nitrogen as nitrates. In the Illinois river at Averyville and at Grafton, in the Kankakee river at Wilmington, the Fox river at Ottawa, the Big Vermilion near La Salle; the Sangamon river at Chandlersville for the four months period, June, July, August and September, 1899 and 1900, and as this has been discussed elsewhere, it is not necessary to do more than to refer to it at this point.

Table No. 15 is reproduced on page 5479.

Q. Professor, can you institute any comparison based upon the tables of analyses of the waters of the Illinois river with the different points on that river?

A. Yes, I have studied the proportions of various constituents as contained in the waters of the Illinois river at various points along its course.

Q. Will you submit those, please?

A. And in consideration of this matter, I will refer to plate No. XXXVII, which has heretofore been offered in evidence and is reproduced on page 5483. It represents seasonal variations in the proportion of chlorine in the waters of the Illinois river at Morris, La Salle, Averyville, Havana and Kampsville for the years 1896 to 1900 inclusive. Upon an inspection of these curves, which are representations of all the analyses made in the respective years for the points considered, the great differences in the content of chlorine, as between the first half and the second half of the year is manifest, these figures being due to the greater volume of water flowing during the first half of the year and the consequent greater dilution of the sewage, while in the second half of the year the dilution was in general very small and the proportion of chlorine naturally greater. Comparison of the line for the year 1900 with those for the preceding year shows that after the opening of the Chicago main drainage channel the proportions of chlorine were very much more uniform throughout the year, the reason being that the dilution in the latter half of the year more nearly corresponded to what it was formerly, or to the natural dilution in the earlier part of the year, that is the flow throughout the year was much more uniform in volume, and consequently the concentration of chlorine in the liquid flowing in the Illinois river never rose to such a height as it in general did during the second half of the year in times prior to the opening of the Chicago main drainage channel.

5485 On Plate XXXVIII, reproduced on page 5484, there are shown lines which represent proportions of the various constituents contained in the waters of the Illinois river at several different points from Lockport to Grafton inclusive. For a number of these points the lines represent averages for

four years analyses preceding the opening of the Chicago drainage channel. Some of the analyses do not cover so long a period, but in every case they cover two years or more. There are also shown in a number of cases the average proportions of the constituents at these same points during the year 1900; that is, the year just after the opening of the drainage channel. The figures which are represented by these curves, have been taken from the defendants' tables of averages 1 to 15 inclusive, which have been heretofore offered in evidence.

Q. Professor, at the time of adjournment on yesterday you were considering the data in Plate XXXVIII and were explaining the curves on that plate. Will you proceed with this explanation?

A. The proportion of chlorine in the canal water at Lockport is shown by the figures in the table of averages and represented by the line upon the plate, and is a little more than 120 parts per million. The considerable drop in the curve between Lockport and the next point, which is Morris, is due in small parts of course, to dilution with the waters of the Des Plaines river, but is mainly due to dilution with the waters of the Kankakee between Morris and La Salle, the next point. There come in the discharges from several minor tributaries, but the most important diluting factor between these points is
5486 the Fox river. From La Salle to Averyville there is practically no change in the content of chlorine, for although between these points various smaller tributaries discharge into the river, the stream also receives some sewage and waste waters which are quite highly charged with chlorides, and which consequently, notwithstanding the increase in volume which occurs, keep up the proportion of chlorine.

Between Averyville and Havana there is a notable diminution in the content of chlorine, and from there on to Kampsville and down to the mouth, at Grafton, a somewhat continuous decrease is apparent. The proportion at Grafton being 15 parts per million.

The curve for 1900 begins at about the same point, but is intended to show the content of chlorine in the mixture at Joliet, since it is at this point that the different discharges of Chicago sewage come together. The proportion is about one-fourth that of the canal at Lockport, for the earlier period, the difference representing approximately the effect of the dilution produced by the use of the drainage channel. From this point down there is a notable diminution in the proportions of chlorine contained in the water, which in a measure keeps step with the diminution which formerly occurred, but is less considerable from point to point, and finally at the point of discharge into the Mississippi the proportion of chlorine is slightly more than 13 parts per million, which shows the effect of the dilution by the use of the drainage channel as it affected the chlorine content in the discharge from the Illinois river into the Mississippi river during the year 1900.

Oxygen consumed: The lines representing the oxygen consumed both the total and that consumed by the filtered water, show marked diminution between Lockport and Morris, a considerable and somewhat continuous diminution from Morris to Havana, beyond which point the total oxygen consumed increases slightly, so that the proportions required by the water discharged from the Illinois into the Mississippi at Grafton, are greater than they were at either Averyville or Havana, this being in part due to the luxuriant growth of vegetation in the lower stretches of the river, and in part due to the presence of other suspended matters, silt and so on, which during a portion of the year are more abundant in the lower stretches of

5487 the river than they are farther up.

Nitrites: Comparisons of the proportions of nitrogen as nitrites show that before the opening of the drainage channel there were but extremely small proportions contained in the water at Lockport, but notable greater proportions at Morris, the maximum being reached at La Salle. This argues for the greater activity of the oxidizing processes near this point than

at points far above or far below La Salle, for while the proportions of nitrites below this point are always considerable, there is continuous diminution all the way down to the mouth of the river at Grafton.

The curve for 1900, shows similar relations between the different points, but a very notably smaller proportion of the nitrites at points below Morris. It is evident from the curves however, and these curves represent merely the figures of the tables of averages above repeatedly referred to—it is evident from these curves, however, that the zone in which the greatest activity of the nitrifying processes is reached has not been changed in position by the opening of the drainage channel. That is, it appears unmistakably from the data of our analyses and is shown clearly in these curves, that the point where the oxidation is most active, and thorough going, is still in the vicinity of Morris and La Salle. The data of table of averages No. 6 A. W. P., show that the point is somewhere between Morris and La Salle, probably near Ottawa.

That is to say the point of greatest activity is at or near Ottawa.

Nitrates. The lines representing the proportions of nitrates show a remarkable increase in the proportions contained as we proceed from Lockport and Joliet to Morris, and so on to La Salle. The increase of nitrates between Joliet and Morris is due in part to the fact that the waters of the Kankakee river which unite with those of the Des Plaines between these two points, are in certain seasons very highly charged with nitrates but much of it undoubtedly is due to the activity of the nitrifying organisms which in this stretch of the river appear to find the conditions of food supply and dilution most pro-
5488 pitious. The great increase of nitrates between Morris and La Salle must be regarded as practically entirely due to the nitrifying processes which in this stretch of the river complete the destruction, that is the oxidation of the organic matters discharged into the river in the Chicago sewage at

Lockport and Joliet. From La Salle to Averyville there occurs a very considerable decrease in the proportions of nitrates. This is due not to dilution, for no considerable dilution occurs between these points—but to the utilization of nitrates by the vegetation which is extremely abundant in the broad lake-like stretches of the river between these points.

From Averyville down to the mouth of the river there is considerable further diminution in the proportions of the nitrates, and this also is due to the cause referred to above, namely the luxuriant vegetation—both that of the river banks and bed and the floating forms.

The curve representing the proportions of nitrates for 1900 shows similar sets of conditions, although the proportions of nitrates is not so great at Morris as it was formerly, a fact which is undoubtedly due to the greater dilution. At La Salle the proportions more nearly approximate those formerly contained, and below this point, although there takes place a notable diminution in the quantity of nitrates on the way to Averyville and Havana, beyond Havana they again increase. Below La Salle there is no point along the river at which the nitrates are not now present in considerably greater proportions than were found in the river water before the opening of the drainage channel. With respect to these differences in the proportions of nitrates between the two periods in question, it seems evident that the conclusion to be drawn must be that nitrification now takes place at least as completely and it would seem far more completely than before the opening of the drainage channel.

The fact that the proportions of nitrates are less at Havana than at Kampsville and Grafton is undoubtedly due to the fact that the great masses of filth which are discharged into the stream in the vicinity of Peoria and Pekin owe their destruction in part to the utilization of oxygen from nitrates which are brought down in abundance by the waters passing Averyville.

Free ammonia. The line representing the proportions of nitrogen as free ammonia for the period prior to the opening of the drainage channel shows excessive proportions of this constituent at Lockport, the diminution on the way to Morris being chiefly due to the dilution, but that between Morris and La Salle being mainly due to the oxidation of the free ammonia to nitrites and nitrates; to its assimilation by the vegetation of the river and in part undoubtedly to its elimination as free nitrogen gas. Between La Salle and lower points upon the river the diminution proceeds continuously although free ammonia is contained in notable quantities in the water finally discharged into the Mississippi at Grafton.

The line for 1900 shows a much lower content of ammonia at the point of initial discharge of Chicago sewage, but it also shows considerable diminution on the way down the river, although as is apparent from the plate and also from table of averages No. 10, A. W. P., the proportions contained in the water as it passes Kampsville, and is discharged at Grafton, were slightly greater in 1900 than the average for the preceding years.

Albuminoid ammonia.

The line representing the nitrogen as albuminoid ammonia constitutes for the upper part of the river a curve quite similar to that just discussed for the free ammonia, but below Averyville there is a slight increase on the way to Havana, due to the discharge of the refuse at Peoria and Pekin. Below this point the quantity does not further diminish, but on the other hand very slightly increases. Comparison of the line for total albuminoid ammonia with that for the albuminoid ammonia derived from substances in solution shows that while the latter diminishes markedly between Havana and Grafton, the total very slightly increases, owing to the presence of greater proportions of nitrogenous suspended matters in the waters at this end of the river.

Total organic nitrogen.

The line representing the total organic nitrogen shows much the same features as those just referred to, although the proportions of total organic nitrogen are more than twice as much as those of the albuminoid ammonia.

Comparison of the curves for the period 1897 to 1899,
5490 with the curves for 1900 shows how great an effect the dilution produced by the opening of the drainage channel has had, and shows that this effect extends to the mouth of the Illinois river. The fact that the total organic nitrogen and the nitrogen as albuminoid ammonia, do not decrease below Havana, is undoubtedly due to the presence of the enormous masses of vegetation in the waters of the lower river. That the free ammonia does not decrease below the proportions shown for Grafton is doubtless due to its continuous production through the decomposition of the various organisms constituting the plankton, which from time to time complete their life cycles and leave their substances then to enter upon that universal series of transformations to which all organic matters are subject.

These ten sheets contain various tables of monthly averages which have been prepared from the detailed analyses given in tables 1 to 80 of this series, Department of Chemistry, University of Illinois, A. W. P., 1 to 80.

Upon sheet 1, there are the monthly averages for the analyses of the waters of the sanitary canal at Joliet, the west side, for 1901; for the samples taken from the Illinois river at Averyville in 1901; for those collected from the Illinois river at Pekin during the three months, October, November and December, 1901.

On the second sheet, there appear similar monthly averages for the year 1901; samples of water taken from the Illinois river at Kampsville, and at Grafton, and from the Mississippi river at Grafton.

On sheet No. 3 there are data for the year 1902. Monthly

averages made from analyses of samples of water taken from the Illinois river at Kampsville.

On sheet No. 4 there are monthly averages for the waters
5491 of the Illinois river at Grafton, for the year 1899, and for the year 1900, and also for the Mississippi river water at Grafton for the same years, that is, 1899 and 1900.

Upon sheet No. 5 there are given the monthly averages of analyses of samples of water taken from the Illinois river at Kampsville during the years 1897, 1898, 1899 and 1900.

Upon sheet No. 6, similar data for the Illinois river at Kampsville during the year 1901.

On sheet No. 7, monthly averages of analyses of samples of water taken from the Illinois river at Averyville during the years 1897, 1898, 1899 and 1900.

Upon sheet No. 8, monthly averages of analyses of samples of water taken from the Illinois and Michigan canal at Lockport during the year 1901; from the drainage canal at the Bear Trap dam at Lockport during 1901; from the drainage canal at Joliet east side, during the year 1901.

On sheet No. 9 there are given the monthly averages of analyses of samples of water collected from the Illinois and Michigan canal at Lockport during the years 1897, 1898, 1899 and 1900.

Upon sheet No. 10 there are given the monthly averages of analyses of samples of water collected from the Des Plaines river at Joliet during the years 1899 and 1900.

JUDGE SPRINGER: Let these be designated as Defendants' Exhibit C for identification, sheets 1 to 10 inclusive, A. W. P. They are not to be printed in the record, but may be at the request of counsel of either side, incorporated in the testimony hereafter, and are to be held by the Commissioner for reference by counsel on either side if they so desire.

5493 Q. Professor, have you any data which show the conditions of the water in the Illinois river just prior to the

opening of the sanitary canal as to stages of water, temperature, proportions of constituents, etc.

A. I have.

Q. Will you submit that data at this time?

A. The numerical data, that is, the figures resulting from the analytical determinations, have all been introduced in the detailed tables 1 to 80 which have been referred to above, but some of these data, and the data with respect to stages of water and the temperature of the water, I have represented upon Plates Nos. XXXIX and XL, heretofore introduced in evidence and to which I now refer in response to the question of counsel, the plates being reproduced on pages 5494 and 5495.

5496 Upon Plate XXXIX there are shown three sets of curves the upper set representing the proportions of nitrogen as nitrites contained in the waters of the Illinois river at Kampsville during the last six months, that is July to December, inclusive, of the year 1899, and the first six months, January to June, inclusive, of the year 1900. Also the last six months in 1898 and the first six months in 1899, and the last six months in 1897, and the first six months in 1898.

These curves have been prepared with the purpose of bringing together the data which show the conditions as we proceed from the warm summer months to the winter, when the temperature is much lower and on again from the winter to the following summer, where the temperature rises.

With respect to the proportions of nitrogen as nitrites contained in the water of the Illinois river at Kampsville in the fall of 1897, the light continuous line in the upper portion of the plate shows the notable variations of this constituent, in the various seasons of the year, the greatest proportion being found in the latter part of July and August. In the latter part of August, the proportions had decreased to about one-third that which is contained in the water at the end of July and the beginning of August. After this there was a slight increase followed by a notable diminution in the early part of September,

which in turn was followed by an increase to double the proportions found earlier in this same month. During the latter part of September and October the proportions were quite notable, but at the beginning of November and after a considerable reduction at the end of October, they rise again to con-
5497 siderable proportions, which were practically maintained to the end of the year; that is, until the beginning of January of the following year, namely, 1898. In January they rose very considerably, being more than doubled in proportion in the early part of the month, after which there was considerable diminution, and the minimum point was reached at the beginning of March, from which time on there were notable variations, but mainly in the direction of increases in the proportions of nitrogen as nitrites, to near the end of the year.

Following the curve for 1898, that is the last six months of 1898, and the first six months of 1899, which curve is shown as a broken line, we find some analagous variations in the early part of the year, although in the end of July and the beginning of August the minimum proportion of nitrites was reached, with the maximum for this period appearing at the end of August; this followed by a very considerable diminution, the line for the next two months, that is, September and October, following almost the same course as for the preceding year, but with the beginning of November, dropping below the line for the other year, that is, the proportions were very considerably less during November, December, January and February, the line again following much the same course as that for the previous year in the latter part of the period, that is the second quarter of the year 1899.

The third line in this group—that represented as a heavy continuous line, represents the proportions of nitrogen as nitrites during the last six months of the year 1899, and the first six months of the year 1900, beginning with notable proportions namely .1 part per million in the early part of July.

There was a drop to about .05 part per million later in the

month, which was followed by an increase to .09 of a part per million in the latter part of July of this year. This followed by a very considerable decrease until the early part of August. In August several increases and decreases followed each other, but none very considerable until the beginning of September, when the proportions diminished to about one-half of what they had been in the latter part of August. Later in September, there was a notable increase, followed by decreases until we get a minimum figure .02 of one part per million of nitrogen as nitrites in the middle of October. In the latter part of

5498 October an increase again, reaching the maximum early in November, reaching .12 of one part of nitrogen as nitrites per million; this followed by decreases until the minimum was found in the latter part of December, after which an increase took place to the first of January following, namely January, 1900, and in the beginning of the year 1900, there was considerable diminution in the proportion of nitrites continuously until the early part of February after which there was a very slight increase in the proportions from .018 of one part per million upon February 7th, to .023 of one part per million on February 14th, to .022 of one part per million on February 21st, this being followed by diminutions throughout the month of March. The next increase in proportion of nitrites coming in the early part of April, following after which there were the ordinary increases and decreases in the proportions of nitrites similar in character to those which I have referred to above, as taking place in the previous years here considered.

It is evident from these liner, which merely represent the figures in tables 37 to 41 inclusive, that the proportions of nitrites contained in the waters of the Illinois river as they were about to discharge into the Mississippi river, were not during the early months of the year 1900, that is particularly January, February and March, 1900, abnormal. In fact the proportions were very much less than were found in the waters of the Illinois at this same point during the same months of the

year 1898, and while somewhat greater in the first part of January than the proportions found at this point in the year 1899, during the latter part of January and during the month of February the figures were almost identical and beginning with March the proportions were almost uniformly less during the year 1900, until the month of June in the early part of which and in the latter part of May, the proportions rose somewhat beyond those which had existed in the water of the Illinois at this point for this time in the year 1899, but were still less than the proportions which had been found in the water at this point in the preceding year at this time, namely, the year 1898.

The second group, that is the group at the middle of plate XXXIX represents the proportions of nitrogen as free ammonia contained in the water of the Illinois river at Kampsville, for the same periods referred to above in discussion of the nitrites.

5499

The light continuous line represents the proportions of nitrogen as free ammonia contained in the water of the Illinois river at Kampsville during the last six months of 1897, and the first six months that is, January to June inclusive of the year 1898. It is very notable from the curves which merely represent the figures which are given in detail in tables 37 to 41 inclusive above referred to, that the proportions of free ammonia are less in the summer time, the months of July and August, that they begin to increase in September, reaching a considerable proportion about the middle of September, after which they diminish somewhat, but remain of notable proportions without much change either up or down, during the months of October and November, until at the beginning of December there is a very remarkable increase in the proportion of nitrogen as free ammonia, as the colder weather of the winter season approaches or arrives.

From the early part of December, when the proportion found was 1.6 parts per million, there is again notable increase in the proportions of the nitrogen as free ammonia, to the early

part of January when the proportions were somewhat more than two parts per million, after which there is a slight decrease to nearly the middle of January followed by a more considerable decrease to 1.44 parts per million upon the 18th of January, and increase to 1.5 parts per million upon the first day of February, followed by a decrease to 1.24 parts per million on the 8th, and a further decrease to .72 parts per million on the 15th of February, a still further decrease to .956 parts per million upon the 22d of February, and further decrease to .52 parts per million upon the first of March, after which there was more continuous and more considerable successive diminutions until the minimum was reached in April, and from that time to the end of June the proportions never rose to as much as .01 of a part of nitrogen as free ammonia per million.

Following the broken line of this set, which represents the proportions of the nitrogen as free ammonia for the late months that is the last six months of 1898, and for the first six months of the year 1899, we note that in the latter part of the year there were similar variations to those referred to above, but that the proportions did not increase so early in the year,

that is, the proportions found in the water during Sep-
5500 tember were practically similar to those found in the
same water in July and August, but that with the beginning of October considerable increase of the nitrogen as free ammonia took place, the maximum being reached early in November, which was followed by a decrease to the middle of November; this in turn followed by an increase to the latter part of November, the minimum for November being reached at .28 of one part per million upon the 29th. After this there were considerable increases until the maximum proportion of nitrogen as free ammonia for the period now in question was reached, upon January 3, 1899, the proportion being 1.28 parts per million. After this there were diminutions in the proportions of nitrogen as free ammonia until at the end of January, namely, January 31, 1899, there were but .6 parts per million,

which was followed, however, by increases to a maximum of .96 parts per million of nitrogen as free ammonia, upon February 21st. After this there were successive decreases and increases, but on the whole diminutions until the warm weather of the summer period was reached, when the proportions were as usual for this season of the year, less than .1 part per million. Following the heavy continuous line which represents the proportions of nitrogen as free ammonia in the waters of the Illinois river at Kampsville during the last six months of 1899 and the first six months of the year 1900, we find nothing particularly unusual in the proportions of the curve. During the first part of the year the lines follow the course above described for the lines of the same months of 1897 and 1898. In the months of September and October it more nearly corresponds to the curve for the year 1897, showing greater proportions than were found during the year 1898, and proportions somewhat less than the considerable proportions found during these months in the year 1897. About the middle of October there was a decrease of nearly 50 per cent in the proportion of nitrogen as free ammonia, followed by an increase more considerable until the proportions .552 parts per million, upon the first day of November, followed by a slight decrease to the next week, and that in turn by an increase to .688 parts per million on the 22d, and 1.44 parts per million on the 29th of November, 1899. Following this there was a decrease to 1.184 parts per million upon the 6th of December. A further diminu-
5501 tion to .368 upon the 13th of December, and from that time an increase to .672 parts per million upon the 20th of December. Following this increase in the latter part of December there was further increase to the maximum of 2.24 parts of nitrogen as free ammonia per million upon the 3d day of January, 1900; from the 3d of January, 1900, to the 17th of January the same month, there was a decrease in the proportions of nitrogen as free ammonia contained in the waters of the Illinois river at Kampsville, to 1.28 parts per million, and

a further decrease between the 17th of January and the 25th of January. The proportion upon the latter date being 1.04 parts per million. From this date to the 31st of January there is a notable increase in the proportions of nitrogen as free ammonia, the maximum of 1.6 parts per million being reached upon January 31st, the same proportion being found a week later, that is, for February 7th. From which time there was a considerable decrease in the proportions of nitrogen as free ammonia, to .736 parts per million, upon the 14th of February; to .672 parts per million upon the 21st day of February; to .656 parts per million upon the 7th of March; again to .32 upon the 14th of March, an increase to .368 parts per million, upon the 21st of March, and again to .432 parts per million upon the 28th of March. From this time on there were variations in both directions, but the general direction of the curve was in the way to represent the diminutions which are shown in the detailed tables of analyses, as occurring during the warmer summer months.

Comparison of this line representing the conditions with respect to the proportions of nitrogen as free ammonia in the waters of the Illinois river at Kampsville during the last six months of the year 1899 and the first six months of the year 1900, show in general great similarity between the conditions during this period of twelve months and the period of twelve months referred to above, that is, the period July, 1897, to June, 1898, inclusive.

The third group of lines upon this plate gives a representation of the proportions of nitrogen as free ammonia contained in the water of the Illinois river at Grafton thirty miles below the point we have been considering, and within two miles of the point where the discharge of the water from the Illinois into the Mississippi occurs. The heavy continuous line repre-
5502 sents the proportions of nitrogen as free ammonia. The broken line represents the temperature of the water as

taken at the time the samples for analyses were collected. The upper curve represents the height of water as read at Government gauges at Kampsville. The stages are given for Kampsville because at this point there is ordinarily no disturbances due to variations in height of the water in the Mississippi river.

At times back water from the Mississippi river causes higher water above the dam at Kampsville, but this is only in times of extreme high water in the Mississippi, while ordinarily at Grafton the stages in the Illinois river follow uniformly the variations in the stages of the Mississippi river.

MR. JEFFRIES: You mean extremely high water in the Mississippi?

A. Yes, sir. The line representing the proportions of nitrogen as free ammonia in this group have been compared from the figures which appear in tables Nos. 21 and 60 of the series 1 to 80 heretofore read in evidence. The data for the latter part of 1899 and for the first part of the month of January, 1900, being thus derived from analyses of collections made once a week, but beginning with the 24th of January the collections were made more frequently and from the 28th of January, 1900, on, the collections were made each day, that is, until the end of April, and the data from these daily collections are represented in the curve for this section of the period in question.

The stages of water represented by the upper curve of this group are the daily readings, or, rather, the mean of tri-daily readings, as in the other case the stages of water and volume of discharge referred to above in my testimony in discussing the conditions at Kampsville.

In the early part of July, 1899, the nitrogen as free ammonia contained in the wafers of the Illinois river at Grafton increased from .06 parts per million on the 5th, to .176 parts per million on the 12th, following which there was a decrease to

.03 parts per million upon the 19th, after which the proportions were at the minimum until they began to increase in the early part of September, reaching the proportions .24 parts per million upon the 13th, decreasing to .18, and increasing again to .396 upon the 27th of September, these increases being followed by a decrease to .192 parts per million upon October 4th, to .172 parts per million October 11th, to .084 parts per million on October 25th. The decreases to this point being followed by a considerable increase to .404 upon the first day of November, to .48 upon the 8th of November, these increases being followed by a considerable drop to .12 parts per million upon the 15th. An increase then occurred to .16 parts per million upon the 22d, to .88 parts per million upon the 29th, to the maximum of 1.12 upon the 6th of December, the increase being followed by a great decrease to .176 parts per million upon the 13th, which is in turn followed by an increase to .432 parts per million on the 20th, to .88 parts per million of nitrogen as free ammonia upon the 27th of December, 1899. The increase in proportions of free ammonia continued. The proportion upon January 4, 1900, being the maximum for the entire period under consideration, namely, 2.24 parts per million nitrogen as free ammonia.

Slight diminution from the 4th to the 10th occurring, the proportion on the latter date being 2.16 parts per million; after this there was a considerable diminution to .704 parts per million upon the 17th day of January, 1900. After this an increase to .8 parts per million upon the 24th of January to 1.6 parts per million upon the 28th, upon the 29th, upon the 30th and upon the 31st of January; then a decrease to 1.24 parts per million upon the first day of February, 1900, the same proportion being found upon the 2d of February; upon the 3d day of February the proportion being 1.36; upon the 4th day of February a slight increase again to 1.44 parts per million, an increase again upon the 5th to 1.504, and again upon the 6th an increase to 1.52 parts per million; after this upon the 7th a

diminution to 1.36; upon the 8th to 1.28; upon the 9th to .96; upon the 10th to .72; upon the 11th to .576, followed by an increase upon the 12th to .608, and a decrease upon the 13th to .512. Again upon the 14th a slight increase to .544, followed by a greater increase to .8 parts per million upon the 15th. Upon the 16th the proportion being the same, that is, .8. After this, an increase upon the 16th and 17th to .896 and a decrease to the 18th to .768. From this point on there were various minor increases and decreases, the general direction or variation, however, being a diminution toward the minimum, which was reached in the warmer months of the year represented in this period, namely, May and June, for the year 1900. The relation of temperature to the proportion of nitrogen as free ammonia is in part illustrated by the curves in this group, for it is notable that as the temperature diminishes in the autumn months, that is, in September, the nitrogen as free ammonia increases in proportion. In this particular year there was an increase in the temperature of the water in the latter part of October, and in conformity with this there appears, or at least in unison with this there appears a decrease in the proportion of nitrogen as free ammonia; then a considerable fall in temperature of the water in the early part of November was accompanied by an increase in the proportion of free ammonia while the increase in temperature of water later in the month was accompanied by a decrease in the proportion of nitrogen as free ammonia. A very considerable further decrease in temperature during the latter part of November and the early part of December was followed in the early part of December by a considerable rise in the proportion of free ammonia. Toward the middle of December there was again a very considerable diminution in the proportions of the nitrogen as free ammonia, although at this time the temperature of the water remained constant, or but a very slight increase. No other very general relation between the temperature condition and the proportion of free ammonia for this time appear. A

5504

further decrease in the temperature of the water to the freezing point, that is, zero degree centigrade, in the latter part of December was accompanied by a very great increase in the proportions of free ammonia contained in these waters. In the latter part of December and the early part of January, a notable rise in temperature of the water from the freezing point, that is, zero centigrade, to four degrees centigrade, just about the middle of January, which rise in temperature was mainly caused by weather conditions, including the precipitation of rain at this time; these were accompanied by a very considerable diminution in the proportions of nitrogen as free ammonia.

Following this there was again a drop in the temperature of the water to the freezing point, that is, zero degrees centigrade, which was accompanied by another very con
5505 siderable rise in the proportions of nitrogen as free ammonia and later, although the temperature remained practically the same, that is, zero centigrade, there was a considerable dimunition in proportions of free ammonia in the waters of the Illinois at this point which was coincident with a very considerable rise in the stage of water in the river and the volume of flow at this time, which increased very considerably as shown in the various plates upon which the discharges of the Illinois river over Kampsville dam, have been represented.

From the early part of March on, the temperature of the water was gradually rising until the maximum was reached. Of course in the warm summer months, and step by step with this rise in temperature, there were notable diminutions in the proportions of free ammonia, but the very great diminution in the proportions of free ammonia in February and through March, 1900, corresponded throughout with the diminutions and other variations referred to above in our discussion, and the variations of nitrogen as free ammonia in the waters of the Illinois at Kampsville, and were in part occasioned by the high water naturally produced by precipitation as rain during

the latter part of February and March and the early part of April during the year 1900.

5506 As I have represented upon plate XL referred to above, the stages of water in the Missouri river, the Mississipi river and the Illinois river were in the latter part of the year 1899 comparatively low, but in the Missouri river at Fort Bellefontaine and in the Mississippi river at Quincy and at Alton the water was remarkably low just at the end of the year 1899, that is, after having been in general low throughout the later months of the year, that is, throughout the months of October, November and December, there was a very considerable fall in the stage of water in these streams just at the end of December, and in some cases, continuing into the early part of January following, that is, January of the year 1900. After this there was a very considerable increase in the height of the water in the Mississippi river both at Quincy and at Alton and in the Missouri river both at Fort Bellefontaine and at Hermann; Hermann being some considerable distance higher up the Misouri river where but little effect of the height of the water in the Mississippi river would ordinarily be felt, and Quincy being more than 100 miles further up the Mississippi river than is Alton and where no effect upon the height of the water in the Mississippi caused by higher stages or low stages in the water of the Missouri river would ordinarily be felt.

I have put in this curve for Quincy and the section of a curve for Hermann in order to show that the conditions at Alton for the Mississippi river and at Fort Bellefontaine for the Missouri river were not caused in the one river by the conditions in the other particularly, but that they existed also at points considerably farther up each of these streams respectively.

In January, the latter part, it is notable that the Missouri went from a little less—it is notable that the Missouri at Fort Bellefontaine rose from a little less than two feet upon the gauge, to seven feet, a rise of five feet between the early part of the month and the latter part, while the Mississippi river at Quincy also rose from the end of December, being less than one foot upon the gauge—it rose to a little more than three

feet upon the gauge at Quincy in the early part of January, to be followed by a decrease to two feet a little later, and in the latter part of January rising to 3.6 feet. This followed by a decrease to a little less than two feet in the early part of
5507 February, an increase from less than two feet to more than five feet, and a rise of over three feet in the stage of water in the river at this point. Later in this month, that is, February, during the middle, the rise came, the stage of water reached six feet, to be followed by a decrease, that is, a fall in the water to about three feet in the end of the month, but in the early part of March there was a sudden and great increase in the height of the water at Quincy, to approximately 13 feet.

The stages of water in the Mississippi at Alton follow the same general course as indicated by the curve, but were more considerable both in the rise and in the fall. In the end of December, 1899, the water in the Mississippi river at Alton reached the extreme low water stage. From there it rose to three feet in the early part of January following to February but rising again in the latter part of January to more than nine feet upon the gauge. From this date to the early part of February there was a very considerable fall in the stages of the water at this point. It went below the extreme low water point but was almost immediately followed by a rise of more than six feet. From this time on there were minor variations in height, the maximum being reached in the latter part of February, followed by a decrease in the early part of March which in turn was followed by a very considerable rise in the stage of the water a little later in March from which time there was a more or less continuous diminution to the end of the period, covered by this plate.

The lines representing the stages of water in the Mississippi river at Alton follow much the same general direction and in general are much similar in proportion to those representing the stages at Quincy, but the rises at this point are more considerable, and the falls in stage of water also more considerable, that is, the variations up and down are more notable at Alton than at Quincy and conform more nearly to the variations both up and down as shown for the Missouri

river at Fort Bellefontaine and at Hermann, than they do with the upper Mississippi at Quincy.

5508 The low set of curves upon this plate No. XL, reperesent the stages of water above and below the dam at Kampsville, the crest of the dam being at 14.8 feet upon the government gauge, from which the readings are taken at this point.

A curve representing the stages of water below the dam shows the variations which are in part occasioned by the relative stages of water in the Mississippi, in the vicinity of the mouth of the Illinois, while the curves representing the stages of water above the dam vary somewhat in conformity with these. They are not so much and ordinarily in fact are not at all particularly affected by the stages of water in the Mississippi.

On the upper part of this section of the curve a cross line drawn at the horizontal line marked 22 in the scale at the side, indicates a point at which the water in the Illinois river at Kampsville above the dam begins to go over the banks. It is between stage 22 and 23 feet. The fact that the length of time in the year when such conditions as send the water over the banks and in part around the dam prevail, is short, is apparent by comparison of that section of the curve represented by the line 22 feet, with the date scale at the bottom of the set of curves.

Adjourned until 2:00 p. m., same day, Wednesday, November 18th, 1903.

Q. Professor, at the time of the noon recess you had just completed your statement in regard to the stages of water in the Illinois, the Mississippi and Missouri rivers late in the years 1899 and early in 1900. What effect did these conditions and changes have upon the condition of the waters of each of these streams?

A. The conditions of the water of the Illinois river at Kampsville and at Grafton at this time, and the relation of these conditions to the stage of water in the Illinois river have been discussed somewhat in detail in my testimony of this morning and also incidentally in my testimony with respect to

the water at Kampsville and at Grafton given yester-
5509 day, and illustrated or rather represented graphically by plates Nos. XII, XIII, XIV, XV, XVI, XVII, XVIII, XIX, XX, XXI, and XXXIX. The data of the tables series A. W. P., 1 to 80, inclusive, which have been used in preparation of the plates above referred to show that the waters of the Illinois during the first three months of the year 1900, that is, January, February and March, 1900, were in practically the same condition as they ordinarily are in this season of the year as shown by comparison of the data of analyses of the waters collected during these three months of the year 1900, with the data of analyses of samples of water collected at the same points in the Illinois river during the same months of the years 1897, 1898 and 1899.

With respect to the waters of the Mississippi river at this time I would refer to my testimony and discussion of the data of analyses of samples of water drawn from the Mississippi river at Quincy and at Grafton above the mouth of the Illinois river during this period, namely, the months of January, February and March, 1900, and given in the respective tables of series A. W. P., 1 to 80, inclusive, and represented for purposes of illustration and ready comprehension in part in charts XXII, XXIII, XXIV, XXV, XXXIII and XXXIV, respectively. Consideration of the data of the tables referred to shows that early in January of the year 1900, nitrogen as albuminoid ammonia and the total organic nitrogen were present in the waters of the Mississippi at this point, Grafton, in about the same proportions as in the waters of the Illinois, and that in the middle of February, there was a very considerable increase in the proportions of total organic nitrogen as of nitrogen as albuminoid ammonia in the waters of the Mississippi river above the mouth of the Illinois, which increase in these substances was fully as great in the waters of the Mississippi as in the waters of the Illinois river, and was doubtless occasioned by causes similar to those which at this time brought about these increases in the waters of the Illinois, namely, a rise of notable proportions in the height of water in the stream

following upon an unusual fall in the stage of water which in turn had followed a somewhat lengthy period of comparatively low water.

The conditions in the Missouri river as stated in my testimony regarding the stages of water in that stream at the same time that I discussed the stages in the Illinois and Mis-
5510 sissippi were with respect to variations in height of water in the stream similar in character and in extent to those in the Mississippi and similar in character but greater in proportion than those in the Illinois river.

The determinations of the total organic nitrogen and nitrogen as albuminoid ammonia in the samples of water collected from the Missouri river at Fort Bellefontaine show that the variations in height of water in that stream were accompanied by similar variations in the proportions of these constituents of the waters, that is, there was a very considerable increase in the proportions of nitrogenous organic matters contained in the waters of the Missouri just at this time, the latter part of January and the early part of February, of the year 1900.

While my data with respect to the composition of the waters of the Missouri river at this time are not as numerous as those which I have described concerning the composition and the constituents contained in the waters of the Mississippi and the Illinois, the results of those analyses show similar fluctuations and by reference to the data submitted in this case on behalf of the complainant in the case, that is, the tables of results of chemical analyses of waters of the Missouri river made by Professor Teichmann, we find that his results fully corroborate my own with respect to these conditions in the Missouri river water, and being more numerous than my own, having been taken daily in the Missouri river, afford a series of determinations which compared from day to day with those which I obtained for the Illinois and the Mississippi rivers, and show even more conclusively than do my own more meagre data, for this period, a more considerable conformity between the conditions of the water of the Missouri river and the Mississippi river at this time, that is, the complainant's data

for this period show a worse condition in this respect in the waters of the Missouri river at Fort Bellefontaine than do my own less numerous data for the reason that they cover the period more fully and they show complete conformity with the conditions I have stated with respect to the Mississippi river; the data with respect to the free ammonia in the waters of these streams my own for the three rivers, and as corroborative of my data for the Missouri river, and refers to the data

already referred to, presented by the complainant, these

5511 show similar conditions, that is, similar fluctuations and

increase in the proportion of free ammonia contained in the water of each one of these three streams at the time I have mentioned, that is, coincident with the rises in the height of water in these three streams and particularly in the Missouri and in the Mississippi above the mouth of the Illinois during the early part of February and March, 1900.

These conditions involving as they do an increase in the proportions of the various nitrogenous organic maters in the waters of the upper Mississippi and in the waters of the Missouri river, and the increased proportions of these substances and matters which accompany them in the mixture of waters passing down the Mississippi river below the mouth of the Missouri increase them in that mixture, which is drawn into the St. Louis waterworks system at the intake tower at the Chain of Rocks.

The waters in the lower reaches of the Illinois river have not been more greatly charged with organic matters since the opening of the Chicago drainage canal than they were prior to the openng of the canal.

The data to which I have testified and the various plates representing different portions of the data particularly those

referring to the condition of the water in the Illinois

5512 river at Kampsville and at Grafton and testified to

somewhat in detail heretofore by me, show that the water in the lower reaches of the Illinois river is now, since the opening of the Chicago main drainage channel, less charged with organic matters than it was previous to that opening.

I present four sheets. On sheet No. 1 there are special cross sections taken in the Illinois river at Averyville, upon July 21, 1899, and upon November 26, 1901, cross sections at Wesley City taken July 22, 1899; cross section at Peoria at the foot of terminal bridge, taken November 26, 1901, and cross sections one and one-half miles below Pekin taken November 26, 1901. These do not involve complete analyses in any one case. In the first case menteniod, namely, Averyville, determinations of the chlorine, of the oxyegn consumed by dissolved substances; of the free ammonia and the total albuminoid ammonia and the nitrites and the nitrates were made.

Those taken at Averyville in November, 1901, were subjected to determinations of chlorine merely.

Those taken at Wesley City July 21, 1899, were submitted to determinations for chlorine, free ammonia, total albuminoid ammonia, nitrites and nitrates.

The samples collected by the terminal bridge at Peoria and below Pekin were submitted to determinations of chlorine merely.

These cross section were taken for the purpose of noting what if any variations there were in the proportions of constituents contained in the waters at these several points in the Illinois river at different distances across the stream. Sheet No. 2 represents the results of analyses of special cross section samples collected in the Mississippi river at Grafton just above the mouth of the Illinois. Samples collected January 5th, 1897, January 18th, 19, February 15, 1899 May 24, 1899,
5513 and July 28, 1899, and also cross-section samples collected in the Illinois river at Grafton January 5, 1899, and July 28, 1899. Most of these samples were subjected to complete sanitary chemical analyses, such as I have testified to heretofore, with respect to the bulk of the work of this investigation. In a few of these samples a fewer number of determinations were made, as is represented upon the sheet here submitted.

Sheet No. 3 has upon it the results of analyses of samples collected at certan cross sections of the Mississippi river at

Hartford, within a half a mile of the mouth of the Missouri river, a portion of these samples were subjected to complete sanitary chemical analyses. In another portion of them only the chlorine was determined, and in yet another the chlorine and the nitrogen as nitrites were determined. At the bottom of this sheet No. 3 there are several analyses of samples of water collected below the mouth of the Missouri river at different points across the Mississippi within two miles of the mouth of the Missouri, and one sample collected a quarter of a mile within the mouth of the Missouri river.

Sheet No. 4 of this series contains the results of analyses of special cross-section samples collected in the Mississippi river at Alton and at points below Alton, namely, at Hartford, and at the Chain of Rocks opposite the intake tower of the St. Louis waterworks.

5514 JUDGE SPRINGER: The tables are to be known as Defendants' Special Cross Sections Numbered 1 to 4, A. W. P., inclusive, and reproduced on pp. 5515-5522.

5522 The data of the special cross sections made at Averyville show that the waters of the Illinois river are of substantially the same composition, that is, contain substantially the same proportions of chlorine and of other constituents at various points across the stream; that the entire body of water passing this point, in the Illinois river is substantially homogeneous as regards these substances, generally determined in the sanitary chemical analyses of waters.

The chlorine determinations alone is sufficient to show the substantial uniformity of composition of the water at the different points in the cross section, hence the different points across the stream.

The purpose of making such cross-section determinations lies in the fact that when different bodies of water are brought together into one stream, it takes some considerable time for them to mingle completely, and our data show what has repeatedly been referred to in giving my testimony, that at different points in the various streams considered in this investigation the waters from different sources do not mingle completely, so that analyses of samples taken at one point in the

stream at such a place would not fairly represent the composition of the entire body of water passing down that stream opposite said point.

The data with respect to the cross-section samples at Averyville show that by the time the waters of the Illinois containing the discharges from the Illinois and Michigan canal from the Chicago main drainage channel; from the upper Des Plaines river, the Kankakee river, the Fox river and numerous other minor tributary streams and containing sewage discharges from various towns situated upon its banks, have by the time they reach Averyville completely commingled so that the waters passing this point at the Narrows at Averyville, is of uniform homogeneous character, with respect to the constituents referred to.

The cross section at Wesley City, made in July, 1899, involving a determination of chlorine, of free ammonia, of total albuminoid ammonia, of nitrites and nitrates, show that the water at this point is not uniform in character all the way across the stream so far as various significant chemical con-
5523 stituents are concerned. The differences in proportions of chlorine at different points here are not great, but the differences in the proportions of nitrogen as free ammonia are very considerable between the two sides of the stream.

The free ammonia at the east shore at this point was but .256 parts per million, while at the west shore within five feet of the west shore the proportion was 2.24 parts per million of nitrogen as free ammonia. At the other points in the cross-section, namely, one-third distance and two-thirds distance across the stream the proportions of nitrogen as free ammonia were greater than near the east shore, but nowhere near so great as the proportions found close to the west shore of the river at this point. This excess of free ammonia near the west shore of the stream at Wesley City is derived from or was at that time, derived from the discharges of Peoria sewage, including industrial wastes and house sewage, distillery slop, cattle shed slop, refuse and so on, passing down mainly along

the west bank of the river at this point, so that the condition of the water at the west bank at Wesley City is in these respects far inferior to its condition near the east bank, that is, for the time specified,—July, 1899.

The determinations made near the terminal bridge at Peoria and below Pekin, which determinations involve merely the chlorine, show somewhat notable though not considerable variations in the proportions of chlorine at the cross-section points; the greater proportion of chlorine being found near the west shore; the smaller proportion being found near the east shore.

On sheet No. 2, defendants' special cross-sections, No. 2, the cross-section samples collected from the Mississippi river just above the mouth of the Illinois at Grafton, were taken for the purpose of determining whether the waters of the Mississippi at this point were substantially of uniform composition across the stream, and it was found that they were, that there were no very notable differences in the composition at the different points in the cross-section,—the cross-section samples being taken at various intervals, ranging from January, 1899, to July 28th, 1899.

Cross-sections taken in the Illinois river at Grafton
5524 January 5th, 1899, and July 28th, 1899, show substantial uniformity of the composition of the waters of the Illinois at different points across the stream.

Defendants' Special Cross-section Sheet No. 3, containing data of the analyses of cross-section samples collected in the Mississippi river at Hartford half a mile above the mouth of the Missouri river, which samples were collected December 6th, 1899, and July 7th, 1900, and August 17th, 1900, show that the waters of the Mississippi river have not commingled perfectly with the waters of the Illinois river by the time these two bodies of water have reached this point where they are about to come in contact with the waters of the Missouri river, and show that even down to this point the waters of the Illinois river pass down mainly along the Illinois shore, while the

water passing down near to the Missouri shore is mainly the water of the upper Mississippi river.

The cross-section of the Mississippi river taken two miles below the mouth of the Missouri river merely affords evidence of the incomplete commingling of the three bodies of water at this point, and is corroborative of the more extensive series of cross-section analyses which have heretofore been testified to.

Defendants' Special Cross-section Analyses Sheet No. 4 contains the results of analyses of samples of water collected in special cross-sections at Alton, Hartford and at the Chain of Rocks. These samples having been collected at the same cross-section points referred to above, but in addition to the ordinary collection, collections were made at different depths below the surface, for the purpose of determining whether the composition at a given point was the same at different depths below the surface of the water in the river.

They show in general that there was at times considerable difference between the proportions of constituents found in the water at eighteen inches below the surface and at depth from six to ten and up to 30 feet below the surface at points where the water reached such depths.

I have made a few other special collections of waters.
5525 I have not got all the data for them here. I made one series of cross-section collections for determinations of chlorine at LaSalle during the summer of 1899, which showed that at this point at that particular time, the water at different points across the Illinois river beside the wagon bridge at La Salle, was of substantially uniform composition all the way across the stream.

I made also special collections of water from the Illinois river at Grafton for the purpose of noting whether the composition varied at different times in the day, that is, during the 24 hours, and I have that data here on sheet No. 5, Special Collections.

This sheet contains the results of analyses of samples of water collected during 24 hours from the Illinois river at

Havana on June 23d, and 24th, 1899. Again similar collections made November 1st and 2d, 1899, and similar 24 hour collections of water from the Illinois river at Havana, November 1st and 2d, 1897, and August 5th and 6th, 1898.

JUDGE SPRINGER: I now offer this sheet in evidence, to be known as Defendants' Special 24 hour collections No. 1, A. W. P. Reproduced on pages 5526-7.

5528 For the purpose of noting whether the composition of the water in the Illinois river varied greatly during the 24 hours on November 1st and 2d, 1897, samples of water were collected from the Illinois river at Havana, at a point a short distance above the mouth of the Spoon river and Quiver lake, during both the day and the night. Samples taken from the river every two hours during this time were mixed together, thus yielding a composite sample representing the character of the water during the 24 hours covered by these collections, and the data secured by the analysis of said sample given in this table No. 2, Defendants' Special 24 Hour Collection, A. W. P., show that the composition of the water collected in this manner is substantially the same as that of samples collected upon previous days, for the same period and upon days shortly following those, indicating that the ordinary collection of a single sample yields results which are substantially correct for the composition of the water passing during at least the 24 hours in which the period of collection ordinarily falls.

5529 Upon August 5th and 6th, 1898, another similar collection was made at the same point, at Havana, and gave results which were simply corroborative of those referred to above regarding the sample collected at this point November 1st and 2d, 1897.

On June 23d and 24th, 1899, some similar 24 hour collections were made in the Illinois river at Grafton. The collection at this time and place, however, was made under somewhat different circumstances by means of a specially constructed galvanized iron boat or tank; the samples were collected continuously during the 24 hours, that is, every hour, every minute

and every second of the 24 hours. By means of siphon tube connections the water was kept continuously flowing throughout the 24 hours into the sample bottle into which it was taken for shipment to the laboratory and subsequent analysis. At this time but two samples were taken at the same point simultaneously, one eighteen inches below the surface of the stream and the other eighteen feet below the surface of the stream, or about two feet above the bottom, the water at this point at this time in the Illinois river being about twenty feet in depth. These two analyses compared with other analyses of samples collected at about the same time at this point show substantial uniformity therewith, and comparison of the two 24 hour
5330 collections made simultaneously here shows substantial uniformity of the composition of the water at this point throughout the depth of the stream. The chlorines were identical in proportion; the oxygen consumed was somewhat greater in the sample collected near the surface, than it was in the sample collected near the bottom of the river. The free ammonia was precisely the same in both samples, as was also the total albuminoid ammonia, though the dissolved albuminoid ammonia, that is, albuminoid ammonia derived from dissolved substances, was somewhat greater in the water collected at the depth of eighteen feet than it was in the sample collected at the depth of eighteen inches, the suspended matters being greater in the water near the surface at this time.

Total organic nitrogen was found to be slightly more considerable in proportions in the water taken near the surface than in the water taken near the bottom.

The dissolved total organic nitrogen being somewhat greater at the greater depth, and less near the surface; the suspended matters conversely being greatest near the surface and least near the bottom.

Nitrites were .017 parts per million in the sample taken at eighteen inches below the surface, and were .032 parts per mil-

lion in the sample taken at 18 feet beneath the surface, while the nitrates were the same,—1.12 in each case.

In 1901 a series of examinations of water at points in the Illinois river, the Mississippi river and the Missouri river were made by me on behalf of the Sanitary District of Chicago.

These sheets contain analyses of samples of water collected from the Illinois river at Averyville during October, November and December, 1901. Analyses of samples of water collected from the Illinois river at Pekin for the same months, 1901; collected in the Illinois river at Grafton, October, November and December, 1901. The Mississippi river at Grafton, October, November and December, 1901; the Missouri river at Fort Bellefontaine, October, November and December, 1901; the Mississippi river at the Chain of Rocks, the Illinois shore, at the mid-channel.

5531 JUDGE SPRINGER: I offer these tables in evidence to be known as Sanitary District series 1901, A. W. P. Sheets numbers 1 to 21 inclusive. Reproduced on pages 5532-5558 inclusive.

5560 I have prepared plates graphically illustrating the detailed examinations contained in these tables.

Plate No. 101, series 1901, A. W. P., represents the averages for the period of three months, October, November and December, 1901, and those for the same three months in 1899 in parallel columns.

The comparison of the three rivers, the Missouri, the Mississippi and the Illinois, exhibits a very great difference between the Illinois and the Missouri on one hand and the Mississippi on the other, during the periods in question.

This plate represents the average proportions of chlorine in the waters of the Illinois river at Grafton, the Mississippi river at Grafton above the mouth of the Illinois, the Missouri river at Fort Bellefontaine and at four points in a cross-section at the Chain of Rocks, for the months of October, November and December, 1899 and the same months in 1901.

The comparison of the three rivers, that is the Illinois just above its mouth at Grafton, the Mississippi just above the mouth of the Illinois at Grafton and the Missouri river at Fort Bellefontaine, exhibit a very great difference between the Illinois and the Missouri on the one hand and the Mississippi on the other, during the periods in question.

The content of chlorine in the Mississippi is practically the same as in the earlier year, the same in 1901 as in the earlier years.

The content of chlorine in the Mississippi river water was about the same as in the Illinois river. The greater dilution in 1901 has of course manifested itself in somewhat lower chlorine than in the year 1899.

The significance of these features is determined upon the
5561 fact that we have demonstrated elsewhere that the water of the Illinois river does not mix perfectly with the water of the Mississippi on its way from Grafton down to the Chain of Rocks, and that the Illinois river water flows mainly close to the Illinois shore, while the water near the Missouri shore consists mainly of Mississippi river water, mixed only slightly with Illinois river water, though at mid-channel there is more or less considerable mixing of the waters of the two streams. That these conditions prevail down to the mouth of the Missouri river, the Missouri river water as it enters the Mississippi deflects the Mississippi river water forcing it toward the Illinois shore, and it passes down chiefly toward the Missouri shore. It mixes of course to some extent with the fluid coming down from the upper Mississippi at this point, but it is substantially but slightly mixed Mississippi river water, which is toward the Missouri shore; that is the main body of water from the Illinois river is toward the Illinois shore and it is water of the Mississippi river mixed with but small proportions of the water from the Illinois, which comes into immediate contact with the discharge from the Missouri river when the Missouri river water enters the bed of the Mississippi and it is quite unlikely that any considerable proportion of Illinois river water mixes at

first with the Missouri river water, but rather it is mainly Mississippi river water containing but a small proportion of the water of the Illinois river.

5562

What we have then, briefly stated is, first, a body of Missouri river water passes down the west or Missouri bank; second, the mixture of Mississippi river water with Missouri river water, containing but a very slight proportion of Illinois river water; third, Mississippi river water containing more Illinois river water in the middle; fourth, Mississippi river water mixed with a more considerable proportion of the water of the Illinois river; fifth near the Illinois shore the larger proportion of Illinois river water mixes of course with the Mississippi river water and to some extent also with the water of the Missouri river.

To be sure, there is no fixed line of demarkation between any of these mixtures, but the mixing takes place gradually, and we certainly have combinations such as I have indicated at the different points across stream. Water for samples taken at the Chain of Rocks shows that the water at the Illinois shore contains far less chlorine than does the Illinois river water pure and simple, but far more than does the Mississippi river water above Grafton. There has occurred a somewhat extensive mixing at mid-stream. We find water having almost the same content of chlorine as at the Illinois shore, while at the intake there is less chlorine than in the Missouri river water at Fort Bellefontaine and considerably less than at the Missouri shore. It is to be noted, however, that the collections at Fort Bellefontaine are not quite so numerous as those at the Chain of Rocks. They did not begin for some ten days or so after the time when those taken at the Chain of Rocks began.

The data of the analyses show, and it is evident from the relative heights of these columns that although the Missouri river water did not extend so far across the stream beyond the intake tower in 1901 as it did in 1899, yet, there was no more Mississippi river water and there was no more Illinois river water in the mixture at the intake tower in 1901, that is, after

the opening of the Chicago main drainage channel, than there was in 1899.

Upon chart 102 of this series there are represented the proportions of oxygen consumed or required by the waters of the Illinois river at Grafton, the Mississippi river at Grafton just above the mouth of the Illinois; the Missouri river at Bellefontaine just above its mouth and the Mississippi river at four different points across the stream opposite the St. Louis waterworks intake at the chain of rocks.

The columns representing general averages of analyses of samples collected during three months, October, November and December 1901 and the same three months for the year 1899.

A comparison of the three rivers shows at once that the total oxygen required was much greater in the Mississippi river water than in the Illinois and was still greater in the Missouri river water than in the Mississippi.

5563 It shows further that the oxygen required by matters in solution in the water, was much greater in the Mississippi water than in the water of the Illinois, and less in the Missouri river water than either the water of the Illinois or the Mississippi. In this respect the Mississippi river water was inferior to both the Illinois river water and the Missouri river water. A cross-section at the Chain of Rocks shows that in 1901 there was a greater difference between the two sides of the river and particularly between the waters passing down the side of the intake tower and that passing down along the Illinois shore than in 1899.

Comparison of the three rivers shows too a considerable improvement in the Illinois river in 1901 as compared with its condition in 1899, and an improvement too, in the Mississippi river in 1901 as compared with its condition during the same period of 1899.

While the conditions in the Missouri river were worse during this period in 1901 than they were in the same period in 1899.

5564 Chart No. 103 of this series represents the average proportions of nitrogen as albuminoid ammonia contained in the waters of the Illinois river at Grafton, the Mississippi river at Grafton just above the mouth of the Illinois, the Missouri river at Fort Bellefontaine, just above its mouth, and at four different points across the stream of the Mississippi river at the St. Louis waterworks intake at Chain of Rocks. Data from which these averages represented upon the charts are made, which averages are upon sheet 21 of the series, covering the three months, October, November and December, 1899 and 1901.

The conditions with respect to the proportions of albuminoid nitrogen as revealed by this chart is somewhat similar to those exhibited by chart 102, representing the proportions of oxygen required; that is, the total albuminoid oxygen was greater in proportion in the Missouri river water in 1901 than in either the Mississippi or the Illinois, while the albuminoid nitrogen in solution was less in the Missouri than in the others.

In 1889 the conditions in these respects were much worse than in 1901, although in the Illinois river, and in the Mississippi river, and the cross-section at the Chain of Rocks, there is shown much less mixing of the water of the Mississippi river with that of the Missouri at the intake tower during the autumn of 1901, than existed in the corresponding season of 1899.

Chart No. 104 of this series represents the total solids, both mineral and organic matters in the waters of the Illinois river at Grafton, the Mississippi at Grafton just above the mouth of the Illinois; the Missouri river at Fort Bellefontaine, and so on, the same points as referred to in the three preceding charts of this series, and is based upon similar averages covering the two periods of three months each, namely October, November and December, 1899 and October, November and December, 1901.

Comparison of the three rivers shows that the total solids in the Illinois river water were notably less in proportion in 1901 than in 1899, and the same is true concerning the water of

the Mississippi river. On the other hand the water of the Missouri contained considerably more total solids in 1901, than it did in 1899, the mineral matters in solution too, are very much greater in quantity in the Missouri river water than in the Mississippi river water, and are notably greater than in the Illinois river water, but the greatest difference between the
5565 Missouri river water on one hand, and the Mississippi and Illinois on the other, is in the proportions of suspended matters, the suspended matters in the Missouri river water during this period in 1899 amounted to about 448 parts per million, while during the season of 1901 they amounted to 906 parts per million. During the same periods the proportions of suspended matters in the Illinois river averaged about 42 parts per million for both years.

In the Mississippi river water in 1899 there were about 55 parts of suspended matters per million. In 1901 about 32 parts per million. It would seem that during these periods the averages representing the quantities of matters in suspension constitute the best basis for calculation of the relative proportions of water from the three streams contained in the mixture at the points where the three have more or less come together.

A comparison of the data at the Chain of Rocks where we note the relative quantities of the suspended matters at the four different points across the stream, shows at once that there is far less mixing of the Illinois river water with that of the Mississippi and that of the Mississippi with the Missouri in 1901, that is after the opening of the Chicago main drainage channel than there was in 1899, the season just preceding the opening of the drainage channel. The relative proportions of suspended matters contained in these waters at the several different points across the stream at the Chain of Rocks and also in the three different rivers are shown more in detail upon chart 105, that is upon this chart, instead of having the averages for the entire period represented by columns, there are lines, that is, curves, which represent the proportions contained in the water on the day of each collection. The very notable in-

crease in suspended matters in the Illinois river, December 16, 1901 appears to be due to the fact that the Mississippi and Missouri rivers fell greatly and suddenly at this time, and created a rapid current in the lower Illinois, that is, particularly between the Kampsville dam and Grafton, thus causing a scouring out of the Illinois river along this stretch. The conditions which prevailed during the same season in 1899 are exhibited upon chart No. 106.

Comparison of the two charts shows how much greater
5566 were the differences between the Missouri river water on the one hand and the Illinois and Mississippi river water on the other and how much less complete was the mixing of these waters at the Chain of Rocks in 1901 than it was in the corresponding season of 1899.

The total solids in suspension are shown in detail upon chart No. 107 of this series, and this again exhibits the great difference between the water at the intake tower and that passing down near the Illinois shore, and also shows that there is comparatively little mixing even so far across the stream as the mid-channel of the Mississippi river; that is a point somewhat to the east of the intake tower.

The fact that the water at the Missouri shore itself frequently contains less suspended matters than that at the intake tower is undoubtedly due to the fact that in times of low water the main current is further out from the shore and beside the intake tower, while the water nearer to the Missouri shore flowing with less velocity does not retain so much matter in suspension as does that farther out, which is moving more swiftly.

The solid matters in solution both at the different points at the Chain of Rocks and in the three separate rivers, are shown upon chart No. 108. The features exhibited with this chart show again that between the mixture of the Illinois river water and the Mississippi river water, which is passing along the Illinois shore, and the Mississippi river water which hugs the Missouri shore, is a body of water consisting chiefly of upper

Mississippi river water which intervenes between that coming down the Illinois shore and the body of water passing down beside the intake tower, and the Missouri shore, and substantially prevents the Illinois river water from reaching the body of water which enters the intake of the St. Louis waterworks.

The relative quantities of total solid matters that is both the matters in solution and those in suspension, contained in the waters of the different streams are shown on chart No. 109, which simply corroborates what has been stated above respecting the significance of the lines of charts 107 and 108, and the others of this series.

JUDGE SPRINGER: I now offer these charts in evidence as Defendants' Exhibits 5, 6, 7, 8, 9, 10, 11, 12 and 13.

(Charts not reproduced in print.)

5567 The proportions of organic matters in the Illinois river near the mouth have been less since January, 1900. I have data bearing upon that in form different from that in which it has already been presented. It has gone in the detailed tables No. 1 to 80 inclusive, which we have been discussing and it was incidentally contained in the tables of monthly averages which were introduced yesterday.

I now have in hand certain tables which bring together the averages of the different constituents for the different years in order to facilitate a ready comparison, a comparison which may indeed be made by study of the detailed tables or by study of the tables of monthly averages, but which being here brought together are more easily considered, and their significance more easily grasped.

I have it in the form of tables here, typewriten tables much of it; some of it I have only in my original personal note book.

The tables are designated Combined monthly and yearly averages of proportions of certain chemical constituents of the waters of the Illinois river at Kampsville, and are numbered from 1 to 7.

A. Table No. 1 of this series gives the proportions of

total organic nitrogen as determined by the Kjel Dahl process in the water of the Illinois river at Kampsville during the years 1897, 1898, 1899, 1900, 1901 and 1902, both for the monthly averages and the yearly averages. These represent the monthly averages of analyses for each year during the period, and the yearly average has been made from all of the detailed analyses made during the year.

5568 The averages for the entire years 1897, 1898 and 1899 have been combined into an average for the three year period, and also the yearly averages for 1900, 1901 and 1902, have been combined into an average for that three year period. The three years average prior to 1900 is 1.0866 parts per million of total organic nitrogen, and for the three years subsequent to the opening of the Chicago main drainage channel, that is, for the three years 1900, 1901 and 1902; the composite average is .8966. Calculating the percentage difference between these two averages, it appears that there has been a decrease in the proportions of total organic nitrogen in the waters of the Illinois river since the opening of the Chicago drainage channel, amounting to 17.48 per cent. Direct determinations of the total organic nitrogen were discontinued after September, 1901, and from that time on to the end of 1902, the data which appear in these tables have been calculated from the relation between the proportions of nitrogen as total organic nitrogen and nitrogen as albuminoid ammonia, on the basis of the nitrogen as albuminoid ammonia, constituting forty per cent of the total organic nitrogen.

The tables here referred to are reproduced on the pages of the record on which reference is made to them.

5569 Upon table No. 2 of this series there is shown similar averages both monthly and yearly, for the disolved organic nitrogen, that is, the total organic nitrogen held in solution or contained in substances which are in solution in the water. The general averages for the three year periods are given at the bottom; they are .636 for the period 1897 to 1899 inclusive, and .522 for the period 1900 to 1902 inclusive. The percentage difference between these is 17.92 which shows a de-

crease in the proportions of the organic nitrogen derived from dissolved substances, since the opening of the Chicago main drainage channel, of 17.92 per cent.

5570 Table No. 3 of this series gives in similar way the monthly averages and yearly averages of proportions of nitrogen as albuminoid ammonia, for the years 1897 to 1902 inclusive, and at the bottom of the sheet there are given also the averages for the first six months and the averages for the second six months. In addition, at the bottom there is given the general average for the three years period, 1897 to 1899 inclusive, and the three year period, 1900 to 1902, inclusive, that is for the three years immediately preceding the opening of the Chicago main drainage channel and the three years immediately following the opening. The general average for the earlier period is .4665 parts per million; for the period immediately following the opening is .3495. The difference between these two amounts to 25 per cent, showing that the decrease in the proportions of nitrogen as albuminoid ammonia, immediately following and for the three years period subsequent to the opening of the Chicago main drainage channel, is 25 per cent.

5571 Table No. 4 of this series represents similar facts. The data with respect to the nitrogen as free ammonia in the waters of the Illinois river at Kampsville, that is, the average monthly proportions and the yearly averages for the years 1897 to 1902 inclusive, and contains also the general averages for each of these three year periods, the average for the three years prior to the opening of the Chicago main drainage channel, was .3717; for the three years period subsequent to the opening of the Chicago main drainage channel, the average was .3957, the relation of these to each other being such as to show an increase in the proportions of nitrogen as free ammonia of six per cent.

5572 Table No. 5 of this series gives similar data with respect to the nitrogen as nitrites contained in the waters of the Illinois river at Kampsville, for the years 1897 to 1902 inclusive, both the monthly averages, the yearly averages and the general averages for the three years period prior to and the

three years period subsequent to the opening of the Chicago main drainage channel.

The average for the former period is .0672, and for the latter period is .0405, manifesting thus, the fact that there was a decrease of 40 per cent in the proportions of nitrogen as nitrites contained in the waters of the Illinois river at Kampsville on the average of three years period subsequent to the opening of the Chicago main drainage channel from the proportions contained on the average during the three years period prior to that opening.

Table No. 6 represents by means of monthly averages and yearly averages as in the other tables of this series, the proportions of nitrogen as nitrates, contained in the water of
5573 the Illinois river at Kampsville during the years 1897 to 1902 inclusive. There are given also the general averages for the three year period prior to the opening of the Chicago main drainage channel, and for the three year period subsequent thereto. The relation of these general averages is such as to show an increase in the proportions of nitrogen as nitrates subsequent to the opening of the Chicago main drainage channel of 15 two-thirds per cent.

Table No. 7 represents the monthly averages of proportions of suspended albuminoid ammonia, that is albuminoid ammonia derived from suspended matters contained in the waters of the Illinois river at Kampsville for the years 1897, 1898 and 1899, and for the years 1900, 1901 and 1902.
5574 The general averages for the three year period before the opening of the main drainage channel is .2794, and for three year period subsequent thereto, was .2265, showing a decrease in the proportions of nitrogen as albuminoid ammonia derived from suspended matters, of 19 per cent.

The quantities of organic matters in the Chicago sewage
5575 discharged into the Des Plaines river are greater since the opening of the Chicago main drainage canal than they were prior to that opening.

My data touching this question bears reference chiefly
5575 to the quantities of nitrogen in the form of free ammonia and nitrogen held in organic combination, and determined by the Kjel Dahl process, in the waters of the Illinois and Michigan canal at Lockport, for the years 1896 to 1902 inclusive, and for the waters of the Chicago main drainage channel for the years 1900 and 1901.

The analytical data of defendants' table of averages No. 1, heretofore introduced in evidence, show that the average proportion of nitrogen as free ammonia in the waters of the Illinois and Michigan canal at Lockport for the four years 1896 to 1899 inclusive, was 13.5 parts per million, and the total organic nitrogen determined by the Kjel Dahl process was 5.3 parts per million.

The average volume pumped into the canal, which was 36,000 cubic feet per minute during these four years, amounts to 1,623,000 tons of water or sewage every 24 hours, which gives us the factor 1.623 for calculating the total weight of nitrogen carried in the canal.

Q. Which canal was this?

A. The Illinois and Michigan canal at Lockport.

5576 We thus find that the discharge of nitrogen as ammonia, that is 13.5 times 1.623 was 21.9 tons per day, that is per 24 hours, and the total organic nitrogen, 5.3 times 1.623, equal to 8.6 tons of total organic nitrogen per day, the sum being 30.5 tons of total nitrogen, that is nitrogen in the form of free ammonia, and nitrogen in organic combination as determined by the Kjel Dahl process.

I have left out of account the very minute quantities of nitrogen as nitrates for the reason that these are forms of nitrogen in combination with oxygen and hence not regarded as so nearly allied to organic substances as is the nitrogen as free or saline ammonia. The 8.6 tons of total organic nitrogen represents 53.75 tons of protein or nitrogenous organic matters, and the 21.9 tons of nitrogen as free ammonia if presumed to have been originally in the form of protein or albuminoid mat-

ters, would represent 136.9 tons of nitrogenous organic matters. Upon this basis the total quantities of nitrogenous organic matters discharged through the Illinois and Michigan canal, before the opening of the Chicago main drainage channel would amount to 190.7 tons per 24 hours.

It is probable that the population contributing to the sewage which flows into the Chicago river, and was transferred from the Chicago river to the Illinois and Michigan canal during the period in question, excreted 34 tons of urea per 24 hours, corresponding to 15.7 tons of nitrogen, and that the major part of the 21.9 tons of nitrogen as free ammonia contained in the water of the Illinois and Michigan canal was derived from this source, and not from the more complex nitrogenous organic matters or proteid bodies. The quantities of organic matters contained in the waters of the canal however, were undoubtedly far less than the total quantities of these matters discharged into the river by the proportion of the population considered, the difference being in very large measure due to the putrefactive changes which begin in the sewers and proceed actively in the river. The changes which formerly occurred in the waters of the Chicago river were similar in most respects to those which take place in the so-called septic tanks, and which serve to destroy much of the organic matter, some of it being converted into comparatively inoffensive sludge, and another portion into gaseous substances which partly escape into the air, some of them characterized by disagreeable odors, but others, as free ammonia, carbon dioxide, nitrogen, hydrogen, and so on, being comparatively inoffensive. The fact that ordinarily there was but very slight difference between the quantities of these matters contained in the water of the canal at Lockport, and the quantities contained at Bridgeport, which has been shown by the comparative analyses of samples collected at these two different points, one at the beginning of the Illinois and Michigan canal at Bridgeport in Chicago; the other at Lockport, the point now under consideration, would appear to indicate that

5577

the putrefactive or septic changes which went on in the river proceeded approximately as far as under these conditions it was possible that they should go, and that the matters remaining in the waters of the canal were in a proper condition for the speedy reception of those changes which mark the next step in the oxidation of the nitrogenous organic matters and their transformation into inocuous products, that is to say, putrefactive changes appear to have approached completion and the conditions become such that no further changes took place, revealed within the canal itself; but the next succeeding step in oxidation and putrefication was facilitated by dilution, of the sewage, and also by introduction of bacterial forms of a different character, derived from or contained in the diluting waters of streams tributary to the Des Plaines and the Illinois, or in the waters of the upper Des Plaines when these waters were sufficient in volume to have marked diluting effect upon the concentrated, but ripened sewage discharged from the canal into the Des Plaines river at Lockport in the main, but in particular at Joliet, three to four miles below.

Since the opening of the sanitary canal of Chicago,—or the main drainage channel, the larger part of Chicago sewage experiences its initial dilution in the Chicago river and passes through the main drainage channel in which the mean daily flow for 1900 was 188,340; for 1901, was 241,323, and for 1902 was 257,006 cubic feet per minute.

5578 The volume of sewage pumped into the Illinois and Michigan canal which is now intended to subserve purposes of navigation only, or for purposes of navigation and to supply hydraulic power to the Norton mills at Lockport, was reduced from the former average of 36,000 cubic feet per minute to 26,700 cubic feet per minute in the year 1900, and to about 23,000 cubic feet per minute during the seven months, May to November, inclusive, in the year 1901; the pumps at Bridgeport standing inoperative during the other months of the year 1901,—the daily and weekly variations in flow of the Illinois and Michigan canal and of the Chicago main drainage channel,

as also the daily flow of the upper Des Plaines river, measured at Riverside, are shown in plates which have been introduced in evidence.

Throughout 1900 and during such part of 1901 as the pumps were in operation, the Illinois and Michigan canal discharged from 40 to 45 per cent of the nitrogen contained in that part of Chicago's sewage which is conveyed into the Des Plaines river, and thence into the Illinois river; the other 55 to 60 per cent during this period passing through the main drainage channel.

That the disposition, that is, the destruction of the organic matters of the sewage by the natural processes which are in operation in the waters of the sanitary canal, the Des Plaines river and the Illinois river, are facilitated by the increased dilution affected by the operation of the Chicago main drainage channel, has been demonstrated by the investigation of the waters of the Illinois river at Averyville and Kampsville as heretofore testified to by me.

The data in the following tables have been calculated from the average daily flows for each month, in each canal, and the monthly averages of the analytical data.

These tables are known as Quantities of nitrogen as free ammonia, and total organic nitrogen, in the Chicago
5579 sewage discharged into the Des Plaines river, being numbered 1, 2 and 3, and I will put them in as we reach them.
5580 Concerning the flow in the Illinois and Michigan canal during the four years prior to the opening of the Chicago main drainage channel there is no detailed evidence, but the engineers of the Chicago Sanitary District and the engineer to the State Board of Health and others who have studied the question, have given as the mean daily flow, during these years, the volume of 36,000 cubic feet per minute. For the year 1900 the flow has been computed by the engineers of the Sanitary District of Chicago, and are printed in the report of streams examinations, which has been discussed in the conduct of the case now being tried.

From the data contained in that publication which has been furnished to me in duplicate by the engineers of the Board, I have computed the monthly average or the mean daily
5580 flow for each month in the year 1900, and these are as follows:

| | | |
|---|---|---|
| January, | 35,156 | cubic feet per minute, |
| February, | 38,104 | do. |
| March, | 37,326 | do. |
| April, | 31,921 | do. |
| May, | 28,740 | do. |
| June, | 23,188 | do. |
| July, | 25,616 | do. |
| August, | 23,730 | do. |
| September, | 25,977 | do. |
| October, | 24,060 | do. |
| November, | 22,521 | do. |
| December, | 13,778 | do. |

The mean for the year being 26,768 cubic feet per minute.

From these I have calculated the flow in tons, and give data in units of one million tons per 24 hours. These data are as follows:

January, 1.582, which signifies that there were 1,582,000 tons of sewage, or water pumped into the Illinois and Michigan canal at Bridgeport, on the average for each 24 hours during the month of January, 1900.

| | |
|---|---|
| February, | 1.71468 |
| March, | 1.68 |
| April, | 1.4364 |
| May, | 1.2933 |
| June, | 1.0345 |
| July, | 1.1527 |
| August, | 1.06785 |
| September, | 1.168 |

| | |
|---|---|
| October, | 1.0827 |
| November, | 1.013445 |
| December, | .62 |

From these data as to the flow in weight of water, the unit is 1,000,000 tons of water or sewage or mixture per 24 hours.

5581 There was no flow in the Illinois and Michigan canal, that is the pumps at Bridgeport were not in operation until the end of April in the year 1901, and the amount pumped during the months of May, June, July, August, September, October and November are as follows:

| | | |
|---|---|---|
| May, | 23,000 | cubic feet per minute, |
| June, | 23,000 | do. |
| July, | 23,000 | do. |
| August, | 23,300 | do. |
| September, | 24,000 | do. |
| October, | 24,500 | do. |
| November, | 20,100 | do. |

December there was no pumping done; there was nothing discharged.

Calculated into tons per 24 hours and units of one million tons, these are, for

| | |
|---|---|
| May, | 1.035 |
| June, | 1.035 |
| July, | 1.035 |
| August, | 1.0485 |
| September, | 1.05 |
| October, | 1.1 |
| November, | .9045 |

The average for the period of seven months being 1.034.

The flow in the drainage canal, that is the discharge at the Bear Trap dam during the year 1901, the mean per 24 hours for each of the twelve months, was as follows:

5582 Cubic feet Tons per 24 hours in units

| Month. | per minute. | of one million. |
|---|---|---|
| January, | 285,000 | 13.27 |
| February, | 304,800 | 13.7 |
| March, | 317,700 | 14.3 |
| April, | 275,000 | 12.37 |
| May, | 190,000 | 8.55 |
| June, | 175,000 | 7.87 |
| July, | 180,000 | 8.1 |
| August, | 236,000 | 10.6 |
| September, | 234,000 | 10.53 |
| October, | 230,000 | 10.35 |
| November, | 234,000 | 10.53 |
| December, | 246,000 | 11.07 |
| Mean for the year, | 242,000 | 10.89 |

The flow in the Chicago main drainage channel for the year 1900, that is, the mean flow per 24 hours for each month and the tons of discharge in units per million, are as follows:

| | | |
|---|---|---|
| January, | 179,682 | 8.08 |
| February, | 138,834 | 6.36 |
| March, | 125,935 | 5.66 |
| April, | 106,644 | 7.36 |
| May, | 161,400 | 7.46 |
| June, | 193,542 | 8.71 |
| July, | 203,447 | 9.155 |
| August, | 224,256 | 10.19 |
| September, | 138,417 | 6.21 |
| October, | 171,490 | 7.717 |
| November, | 228,775 | 10.3 |
| December, | 254,900 | 11.47 |

I haven't got the year's average stated here, but I have it somewhere else. I can easily supply that. We will not wait for it now.

Q. Professor, you will now proceed with the explanation of table 1 heretofore referred to and put in evidence?

A. Table No. 1 shows the discharge of nitrogen as free

ammonia from the Illinois and Michigan canal and the
5583 Chicago main drainage channel, or sanitary canal in tons per 24 hours, during each of the months of the year 1900, and the year 1901, the figures in the column opposite each month representing the mean discharge of nitrogen as free ammonia for each 24 hours throughout the month represented. There is shown also the mean discharge in tons per 24 hours for the year both from the Illinois and Michigan canal and from the sanitary canal or drainage channel, and the sum of these, which represents the total amount of nitrogen in the form of free ammonia contained in the sewage discharged by means of these two canals from Chicago or by Chicago into the Des Plaines, and thence into the Illinois river, the mean flow in cubic feet per minute for the Illinois and Michigan canal for the year 1900 is stated at the bottom of the column designated "I. & M." The mean daily flow or discharge from the sanitary canal for the year is stated at the bottom of the column designated "Sanitary" for 1900, and is 188,340 cubic feet per minute.

The fourth column in this table contains the sum of the nitrogen as free ammonia discharged by the Illinois and Michigan canal and that discharged by the main drainage channel or sanitary canal.

The fifth column in this table contains the figures showing the quantities of nitrogen as free ammonia discharged by the Illinois and Michigan canal during the year 1900.

It will be noted that during the first four months nothing appears in this column for the reason that there was no discharge, the pumps at Bridgeport being left inactive during this time, and again during the month of December, the blank is present for the reason that there was no pumping and no discharge from this canal during the month of December, 1901.

The figures for the sixth column represent the quantities in tons per 24 hours of nitrogen as free ammonia discharged by the sanitary canal and in the 7th column there appears the sum of the nitrogen as free ammonia discharged by the Illi-

nois and Michigan canal and by the sanitary canal for each month during the year 1901. The figures in this column representing the total discharge per 24 hours of nitrogen in the form of free or saline ammonia in the Chicago sewage sent through these two canals into the Des Plaines and thence
5584 into the Illinois river; the mean flow for the seven months of 1901 during which there was a discharge from the Illinois and Michigan canal, was 23,000 cubic feet per minute; the mean daily discharge from the sanitary canal during this year being 242,323 cubic feet per minute.

The aevrage flow of the Illinois and Michigan canal during the years 1896 to 1899 is given as 36,000 cubic feet per minute. Upon this basis calculations from the figures representing the average content of nitrogen as free ammonia in the waters of the Illinois and Michigan canal at Lockport during the years 1896 to 1899 inclusive, which appear in defendants' table of Averages No. 1, A. W. P., show that the average discharge of nitrogen as free ammonia in the Chicago sewage sent into the Des Plaines river during the years 1896 to 1899 inclusive, was 21.9 tons per 24 hours and that during the year 1899 the year immediately preceding the opening of the Chicago drainage channel the quantity of nitrogen as saline or free ammonia thus discharged into the Des Plaines river in Chicago sewage was 22.5 tons per 24 hours.

The nitrogen as free ammonia represented in the table, that is, for the discharge by the sanitary canal, .2 of one ton per 24 hours, was contained in the diluting lake water drawn through the Chicago river, and not in the sewage discharged into the Chicago river.

Table No. 1 is reproduced on page 5585.

5587 Table No. 2, A. W. P., showing quantities of nitrogen discharged into the Illinois river in Chicago sewage; total organic nitrogen discharged into the waters of the Illinois and Michigan canal and sanitary canal, tons per 24 hours.

5589 Table No. 3 shows quantities of nitrogen discharged into the Illinois river in Chicago sewage; total nitrogen, i. e., sum of the nitrogen as free ammonia, and the total organic nitrogen discharged by the two canals. Tons per 24 hours.

5592 These tables numbered 4, 5, 6, 7, 8 and 9 of this series give the mean daily discharge of nitrogen in the form of free or saline ammonia, in the form of albuminoid ammonia, the total organic nitrogen and nitrogen as nitrites, and the nitrogen as nitrates, in the waters of the Illinois river discharged over the Kampsville dam for the years 1897 to 1902 inclusive, and also show the average discharge per 24 hours for the first six months and the second six months in each year referred to, and the average discharge for the entire year. Also the average discharge for the period of three years prior to 1900, and the average daily discharge for the three year period 1900, 1901 and 1902, inclusive, thus covering the three year period immediately preceding the opening of the Chicago main

5593 drainage channel and the three year period immediately subsequent thereto.

The computations of these quantities have been made in similar manner to the computations of the quantities of nitrogen discharged by the Illinois and Michigan canal and by the sanitary canal into the Des Plaines river; that is the computations have been made from the mean daily flow of water over Kampsville dam, and the average content of the constituents for the month in question, the mean daily flow for the first six months, that for the second six months and that for the year, and the average content of the respective constituents for the first six months, and the second six months and the entire year.

The calculations respecting the quantities of nitrogen in different forms of combination in these waters have been made in several different ways, those which appear in Plate 41 represent the total organic nitrogen that has been in tons discharged per 24 hours calculated on the basis of the discharge of water

for the day upon which the sample for analyses was collected, and the proportion of the total organic nitrogen found in the sample collected that day.

Plate 41 is reproduced on page 5594.

5594 The lines of this plate show how considerable were the seasonable variations in the weights of organic nitrogen discharged over the dam at this point during the years 1896 to 1900 inclusive, only the last five months in 1896 being considered because our examinations of the water of the Illinois river at Kampsville began in the latter part of July of that year.

5595 Comparison of these curves with each other shows that during the year 1900, that is, the first year after the opening of the Chicago main drainage channel, the weights of organic nitrogen carried by the water of the Illinois river over the dam at Kampsville, just as they are about to discharge into the Mississippi at Grafton, thirty miles below, were generally less than they were during the preceding years, during both the high water period and the low water period, except that in 1899, during the period ranging from the middle of August to the middle of November, when the flow in the river was extremely low, the quantities of organic nitrogen carried were less than 1900.

Calculations based upon monthly averages both for the data of the analyses and for the flow of the river show similar but of course less irregular variations throughout the years.

Table No. 4, A. W. P. of the series under consideration, is total organic nitrogen; quantities of nitrogen in the Illinois river at Kampsville. Tons discharged per 24 hours and is reproduced on page 5595.

5596 The figures of this table representing the mean daily discharge of total organic nitrogen for the year 1900 have been represented upon plate No. 42, of this series, together with similar lines refering to the quantities carried by the waters of these streams at certain other points during the

same period. Plate No. 42 is reproduced on page 5597.

5598 Comparison of the lines upon this plate, with each other, which merely represent the data which has been introduced, shows that at times there is six times as much total organic nitrogen discharged in the waters of the Illinois river over the dam at Kampsville as is contained in the water of the Des Plaines river at Joliet, which latter comprizes the mixture of the flow from the upper Des Plaines, that from the Chicago main drainage channel and that from the Illinois and Michigan canal.

The difference between the lines for Averyville and Kampsville, indicates the quantities of organic matters brought into the lower Illinois by tributaries and the sewage of Peoria and Pekin and so on which escape oxidation or complete destruction by the time the waters reach Kampsville, or the organic substances of the living vegetation which is present in the lower reaches of the Illinois river.

5599 Plate No. 43 shows seasonal varieties in the relative quantities of nitrogen as albuminoid ammonia, discharged by the sanitary canal at Lockport, the Des Plaines river at Joliet, and the Illinois river at Averyville (North Peoria) and Kampsville. Tons per 24 hours calculated from monthly averages.

5601 Plate No. 44 shows seasonal variations in the relative quantities of nitrogen as free ammonia and as nitrates discharged by the sanitary canal at Lockport, the Des Plaines river at Joliet, and the Illionis river at Averyville (North Peoria) and Kampsville. Tons per 24 hours, calculated from monthly averages.

5602 This plate represents by means of curves, seasonal variations in the relative quantities of nitrogen as free ammonia and as nitrates discharged by the sanitary canal at Lockport, the Des Plaines river at Joliet, the Ilinois river at Averyville, and at Kankakee. The figures representing the discharge in tons per 24 hours, that is the mean daily discharge in tons for each month in the year 1900. So far as the curves represented upon the plate cover the various months of the year.

The lower portion of this plate representing the nitrogen as free ammonia, shows that the quantities of nitrogen as free ammonia contained in the waters of the Illinois river at Kampsville are very much greater during cold weather and high water, that is in January, February and March, than at any other time during the year, and the quantities contained here at Kampsville are at this part of the year several times greater than the quantities discharged with the Chicago sewage into the Des Plaines river at Joliet and Lockport, but later in the year, from May to November, the conditions are just reversed. The quantities of nitrogen as free ammonia contained in the stream at Kampsville and also at Ayersville, being very much less than the quantities found in the waters of the sanitary canal or in the waters of the Des Plaines river at Joliet. The very large quantities of free amonia in January and February are coincident with comparatively low water. See plates 18 and 19 already introduced in evidence. And with the excessively high proportion of free ammonia, see plates 10, 14 and 39 of this series, which is characteristic of the Illinois for the extreme cold weather season. The much greater quantities of free ammonia contained in the waters of the Illinois at Kampsville and other points in March, are derived in a large part from the rain and the surface wash.

Upon plate No. 44, there are also shown lines representing quantities of nitrogen in the form of nitrates. The enormous quantities of nitrates found in the water at Averyville and Kampsvile during March and April, the freshet season, are in the main, derived from the leechings or surface soils by the run-offs and the discharges of tile drains. The decrease at the coming of warm weather and lower water in May and June, results in a partial cessation from this leeching,

5603 from the partial oxidation of the supply of nitrates in the soil and from the assimilation of nitrates by the vegetation, especially that of the plankton, which at this season of the year increases in abundance with very great rapidity during the cold weather season.

5604 Plate No. 45 shows Illinois river at Kampsville, discharge curves, also showing concentration of chlorine

and discharge of chlorine.

5605 Table No. 5 of this series being quantities of nitrogen in the water of the Illinois river, tons discharged per 24 hours at Kampsville, Illinois, reproduced on page 5605.

5606 This table gives the discharge of nitrogen as albuminoid ammonia in the waters of the Illinois river passing over the Kampsville dam in tons per 24 hours, for each month of the year 1897 to 1903, inclusive, and gives also the average daily discharge during the first six months and during the second six months, and for the period, the three year period; also the average, that is, the period prior to the opening of the Chicago main drainage channel and the average for the three years subsequent to that opening, these averages being 20.08 tons per 24 hours, and 14.07 tons per 24 hours, respectively, showing a decrease in the weight or quantity of nitrogen as albuminoid ammonia discharged by the waters of the Illinois river at Kampsville in the second period of three years, that is, the period following the opening of the Chicago main drainage channel as compared with the three years prior thereto, which decrease amounts to 30 per cent in weight.

5607 Table No. 6 being tons of free ammonia. This table gives similar data respecting the discharge of nitrogen as free ammonia or saline ammonia in the waters of the Illinois river passing over the Kampsville dam during the years 1897 to 1902 inclusive. For the three years prior to the opening of the Chicago main drainage channel 10.78 tons of nitrogen as free ammonia every 24 hours, and for the three year period, 1900 to 1902, subsequent to the opening of the Chicago main drainage channel, 11.1 tons of nitrogen as free ammonia every 24 hours, thus showing an increase in the quantity of nitrogen as free ammonia discharged by the waters of the Illinois

5608 at this point in the second period over the quantity discharged during the first period, amounting to practically three per cent, the figure on this plate being 2.968 tons per 24 hours.

5608 Table No. 7 represents the quantities of nitrogen as nitrites discharged into the waters of the Illinois river

over the Kampsville dam for the period 1897 to 1902, inclusive. The discharges appearing as the average daily amount carried by these waters for each month of the year indicated
5609 respectively, the average daily amount in tons during the first six months, the average daily amount during the second six months and the average daily amount during the whole year, and also the averages for the three year period prior to the opening of the Chicago main drainage channel and the average for the three years subsequent thereto, the figures for these two periods being as follows:

For the first, 2.23 tons per 24 hours; for the second, 1.282 tons per 24 hours; showing that subsequent to the opening of the Chicago main drainage channel the proportions of nitrogen as nitrites discharged by the waters of the Illinois river at Kampsville were 42½ per cent less than they were during the three year period immediately prior thereto.

Inspection of the figures representing the data for the year 1902 in this plate, shows the shifting during this year of the high nitrites period, consequent upon the shifting of the high water period as shown upon the plates 19 and 18 heretofore introduced in evidence, which plates show the discharges of water by the Illnois river at Kampsville for the years 1896 to 1902, inclusive, and show the fact that is given in detail in the tables of discharge which have been heretofore introduced in evidence, that while usually the high water period in the lower Illinois river comes in March and April, in the year 1902 the highest water of the year came in July and August, and for the last nine months of the year the water was
5610 throughout, unusually high, in fact, the discharge for the year 1902 was considerably higher than any other year of this period, that is, of the years 1896 to 1902, inclusive.

Table 8 represents the discharge in tons per 24 hours of nitrogen as nitrates, contained in the waters of the Illinois river passing over the dam at Kampsville during the years 1897 to 1902, inclusive, and includes also the average daily discharge for the first six months, and the second six months, and the year.

The data of this table touching the year 1900, has been used in making the curve for this point shown upon plate No. 44 heretofore introduced in evidence.

5611 Comparison of the data for the various years shows that during the year 1897 the quantities of nitrates discharged into the waters of the Illinois river at Kampsville, were very much greater throughout the year, that is, throughout the high water season, and also in general throughout the low water season, than they were in the years 1898 and 1899.

The proportions discharged during the years 1898 and 1899, were on the average considerably less than during the years 1900 and 1901, and still more considerably less than during the year 1902, though in no one of the years subsequent to the opening of the Chicago main drainage channel were the quantities of nitrates in the water of the Illinois at Kampsville so great as they were during the year 1898.

It is notable that for the year 1902 the quantities of nitrates carried in the waters of the Illinois river at Kampsville were much greater during the latter part of the year than during the first two months, and that during what is ordinarily the low water season in the Illinois, that is, the last six months in the year, the nitrates at this point were present in very considerably greater quantities than during the similar periods of the five preceding years, which fact is in the main due to the high water which existed during this portion of the year 1902, an unusual condition as referred to in my testimony above.

The comparison of the monthly averages of the discharges of nitrogen as nitrates per 24 hours for the two points, Kampsville and Averyville, shown in the upper part of Plate No. 44 heretofore introduced in evidence, shows that during the

5612 high water season the discharge of nitrates at Kampsville was less than the discharge at Averyville, while in the latter part of the year, especially during the months of July, August, September and October, the quantities are approximately equal at the two points, in the latter part, that is, in the

months of November and December, there being a somewhat greater quantity of nitrates discharged by the waters of the Illinois at Kampsville and at Averyville.

Table No. 9 shows the discharge of nitrogen as nitrites, nitrates, free ammonia, the total organic and the total nitrogen; also the albuminoid nitrogen and the oxygen consumed by the waters of the Illinois river discharged over the Kampsville dam in tons per 24 hours, during the years 1897 to 1900, inclusive.

5613 The figures representing the average daily discharge of the various constituents mentioned during each of the years referred to and being calculated from the mean yearly flow and the yearly average of the given constituent.

The total nitrogen referred to, the figures representing the quantities of which appear in column 6, consists of the sum of the nitrogen as nitrites, the nitrogen as nitrates, the nitrogen as free ammonia and the total organic nitrogen, and consequently represent all of the nitrogen contained in the waters in combination with different substances. I explained that to distinguish from nitrogen gas, which may be dissolved in the water and which may be formed by the decomposition of any of these substances, or be dissolved from the air.

5614 Table No. 10 has similar data but computed for the first six months of the respective years and calculated from the mean daily flow during the first six months, and the average proportions of the constituents during the first six months of the respective years.

Table No. 11 contains similar averages to those just referred to, but for the second six months in each of the respective years.

5615 Table No. 12 gives the quantities of nitrogen in the waters of the Illinois river at Kampsville in tons per 24 hours discharged; yearly averages calculated from the discharges in tons per 24 hours for each month, which appears in the tables which have just been referred to.

5616 Table 13 shows the quantities of nitrogen in the waters of the Illinois river at Kampsville in tons discharged per

24 hours, calculated from yearly averages of flows and yearly averages of the various constituents, the nitrogen as nitrites and as nitrates, as free ammonia, the total organic as determined by the Kjel Dahl process, the total nitrogen, that is, the sum of that as nitrates, that as nitrites, that as free ammonia and the organic nitrogen, and in addition to these similar data regarding the nitrogen as labuminoid ammonia and also the quantities of oxygen consumed by the waters. The averages for the three years preceding the opening of the Chicago main drainage channel and the averages for the three years immediately sub-

5617 sequent thereto, together with general averages for each of these two or three year periods.

The organic nitrogen ordinarily as determined by the Kjel Dahl process is for the year 1902, in this table computed from the nitrogen as albuminoid ammonia on the basis of the latter constituting 40 per cent of the total organic, the Kejl Dahl determination of organic nitrogen. At the bottom of the table there are also given the mean yearly flows or discharges of water over the Kampsville dam corrected for submergence of the wier for the years 1897 to 1902 inclusive.

(Witness gives data showing flow over the Kampsville dam, by months from 1896 to 1902 inclusive.)

5621 Table 14 represents the quantities of nitrogen discharged in the waters of the Illinois river over Kampsville dam in tons per 24 hours, and is calculated for the first three year period, that is the years 1897 to 1899, inclusive, immediately preceding the opening of the Chicago main drainage channel and for the three year period 1900 to 1902, inclusive, immediately following that opening.

During the first period the average flow was 13,900 cubic feet per second, or 37,530,000 tons of water per 24 hours.

During the second period the flow was 13,614 or 36,750,000 tons of water per 24 hours.

In the table there are given the average proportions of the different constituents and also the average daily discharge in tons of the constituents in question.

The nitrogen as nitrites amounted to 2.52 tons per 24 hours during the first period, and 1.49 tons per 24 hours during the second period, which shows a decrease in the quantities
5622 of this constituent discharged by the water of the Illinois river at Kampsville during the second period, as against the first, of 40.8 per cent.

The nitrates are shown by the table to have increased during the second period, the increase amounting to 13.3 per cent.

The free ammonia discharged was found to be greater in quantity during the second period than during the first to the extent of 3.7 per cent.

The organic nitrogen as determined by the Kjel Dahl process was contained in smaller quantity during the second period than during the first, and as represented upon the table the decrease in weight was 18 per cent.

At the bottom of the table similar data show that the quantities of nitrogen as albuminoid ammonia decreased, the decrease as stated being 30.6 per cent.

The oxygen consumed during the first period amounted to 438 tons per 24 hours, and during the second period 393 tons per 24 hours, showing thus a decrease of 10.2 per cent subsequent to the opening of the Chicago main drainage channel.

The evidence shows conclusively that since the opening of the Chicago main drainage channel there has taken place not only a considerable diminution in the proportions of the organic matters contained in the waters of the lower Illinois river, and as they are about to discharge from that stream into the Mississippi, but that a substantial decrease of the actual quantities of the organic matters contained in these waters has occurred, and this notwithstanding the fact which I have testified to, already, that the quantities of organic matters conveyed in Chicago sewage into the Des Plaines and thence into the upper Illinois are considerably greater now than they were before the opening of the Chicago main drainage channel.

As it has been shown in my testimony that the organic matters contained in the Chicago sewage discharged into the upper Illinois are practically destroyed or converted into vegetable matters by the time the waters reach Peoria, that is Averyville, while another great influx of sewage and other organic wastes occurs, it will be of importance to compare the condition of the water at Averyville, just above Peoria with its condition at Kampsville, 140 miles below, with respect to the quan-

5623 tities of organic matters carried by the stream at these two points.

The data involved in this comparison have been brought together upon table 15 of this series, which is reproduced on page 5623.

Table 15 represents the quantities of nitrogen in the waters of the Illinois river at Averyville, above Peoria, tons discharged per 24 hours; that is, the average for the years 1897 to 1901 inclusive, and with the general averages first for the three

5624 year period before the opening of the Chicago main drainage channel and second, for the two year period immediately following, and also there are introduced here once more, for purposes of comparison, similar data with respect to Kampsville.

Comparing the averages for the three year period before the opening of the Chicago main drainage channel with the averages for the two year period subsequent thereto, and I may say here that no analyses of the waters of the Illinois river at Kampsville were made by me for the year 1902, the work at that point was discontinued—comparison of the general averages for these two periods shows that subsequent to the year 1899 there was a decrease in the weight of nitrogen as nitrites discharged by the waters of the Illinois river at Averyville, from 5.24 tons per 24 hours to 2.34 tons per 24 hours, a decrease of 55 per cent.

The nitrates on the other hand were increased, the increase amounting to 16.85 per cent.

The nitrogen as free ammonia showed a very considerable decrease, amounting to 22.9 per cent, the total organic nitrogen, Kjel Dahl, show a decrease amounting to 17.86 per cent.

The total nitrogen, that is, the sum of those before referred to, show a decrease of 6.26 per cent.

The nitrogen as albuminoid ammonia decreased in quantity 32.78 per cent.

The oxygen consumed by the waters of the Illinois at this point showed a decrease amounting to 25.55 per cent.

Comparing the data for Averyville with those for Kampsville for the years 1897 to 1899, inclusive, the data for Kampsville having been taken from the tables heretofore introduced by me in evidence, shows that between Averyville and Kampsville there is a very considerable decrease in the quantities of nitrites carried by the waters of the Illinois river, this amounting to 48.47 per cent.

That the nitrogen as nitrates during this period increased 14.5 per cent. The nitrogen as free ammonia decreased 43.56 per cent. The total organic nitrogen as determined by the Kjel Dahl process increased 62.15 per cent, this increase being due to the organic matters brought in by the various tributaries of the Illinois, the discharges of organic matters at Peoria and
5625 Pekin and the wash from the immediate water-shed of the river, and including the vegetation of the river which has subsisted upon refuse organic matters, introduced at points above and from the conversion of mineral matters contained in the water, including nitrates, nitrites free ammonia, carbon and so on, into the substances of the vegetation which is so luxuriant in the lower reaches of the Illinois, the total nitrogen is found to increase 7.47 per cent during this period between Averyville and Kampsville.

The albuminoid nitrogen increased between these two points to the extent of 44.39 per cent, considerably less in proportion than did the total organic nitrogen.

The oxygen consumed by the waters increased in quantity between these two points to the extent of 45 per cent.

Comparing the periods after the opening of the Chicago main drainage channel and for the purpose of putting this comparison upon a more reasonable basis I have calculated an average for the content, that is the quantity of these constituents contained in the waters of the Illinois at Kampsville for the two year period following the opening of the Chicago main drainage channel since we have data for Averyville only for this period, we find generally as follows:

A decrease in the quantities of nitrogen as nitrates from 2.34 tons per 24 hours at Averyville, to 1.22 tons per 24 hours at Kampsville, a decrease of 47.85 per cent, which is almost as considerable in percentage as the decrease between these two points in the earlier years, while the actual quantities themselves are about one-half the quantities contained in the water at these two points during the previous period, that is the three years prior to the opening of the Chicago main drainage channel. The nitrates show a change between Averyville and Kampsville, that is, a decrease, amounting to 5.49 per cent, while in the former period between these two points there occurred an increase in the weights of nitrogen as nitrates. The nitrogen as free ammonia were for Averyville during this period 18.88 tons per 24 hours; the quantities for Kampsville being 11.24 tons per 24 hours, showing a decrease of 40.46 per cent between the two points, which is practically the same as the decrease which took place between these two points during the previous period, which was 43.56 per cent, while the
5626 actual quantities contained at both points in the second period were considerably less than they were in the earlier period.

The organic nitrogen as determined by the Kjel Dahl process increased between these two points in this period from 20.88 tons per 24 hours to 27.43 tons per 24 hours, showing an increase of 31.37 per cent, which is but little more than one-half

as much as the increase which took place between these two points in the period of three years prior to the opening of the Chicago main drainage channel. The figure for that period being an increase of 62.15 per cent.

The total nitrogen contained in the waters shows a decrease of 5.16 per cent in this period as against an increase of 7.47 per cent during the earlier period.

The albuminoid ammonia shows an increase of 25.03 per cent as against an increase of 44.39 per cent during the earlier period, the oxygen consumed showing an increase of 27.68 per cent as against the increase of 45 per cent during the earlier period.

The data of this table No. 15 of this series show that the condition of the water of the Illinois river just above Peoria is very much better since the opening of the Chicago main drainage channel.

The data of this table No. 15 of this series corresponds completely with the data of the various tables I have introduced in evidence, in showing that the condition of the water of the Illinois river just above Peoria is very much better since the opening of the Chicago main drainage channel, and that the natural destruction of the organic matters discharged into the river in the sewage is by the time the water reaches Averyville, is far more complete than it was at this point prior to the year 1900.

A comparison of the data for Kampsville with those at Averyville shows that at the like periods which have been referred to (and no examinations of the water at Averyville were made in 1902)—the actual weights of nitrites and of free ammonia carried by the water of the Illinois, decreased more than 40 per cent during the flow from Averyville to Kampsville; inasmuch as the waters of the tributaries of the Illinois contained organic material in proportions equal to those of the Illinois it-

self, and since enormous quantities of nitrogenous or-
5627 ganic matters are discharged into the Illinois at Peoria and Pekin, a few miles below Averyville, a considerable increase in the quantities of nitrogenous organic matters in the waters of the lower Illinois might well be expected, but it is to be remembered that the organic matters in the waters of the Illinois below Havana, 45 miles below Peoria and 88 miles above Kampsville, consist of vegetable matters chiefly those of the plankton, as is shown both by observation and by the results of the general investigations which have been introduced in evidence.

I previously made a statement that the number of cattle fed at the distilleries and in the stock yards at Peoria and Pekin were 40,000 annually. While this was true of previous times, for previous years, the number have in late years been reduced, and I understand that there are now being fed in the distillery sheds at Peoria and Pekin but 18,000 head of cattle annually.

One other correction I wish to make, with respect to the amount of corn used in the glucose works at Geneva, from which discharges of organic matters are made into the Fox river. I stated that 40,000 car-loads of corn per annum were used in these works, while the correct amount, according to my information is 30,000 car-loads of corn per annum, averaging 40,000 pounds of corn per car.

Beginning on page 5627, witness gives a definition of the terms used in rendering his testimony.

By the term "Organic matters" I mean such matters con-
taining carbon in combination as constitute the tissues of
5628 living things or organisms, and as are contained in the various secretions or liquids contained in living things of all sorts, great and small, and some of the products elaborated by living organisms, excreted by them, or built up into their tissues, excluding the carbon di-oxide, which is excreted by certain living organisms, and absorbed and utilized by other living or-

ganisms, but which is commonly regarded as mineral or inorganic substance.

Q. What is the meaning of the words "nitrogenous organic matters in water?"

A. By the term "Nitrogenous organic matter" we mean to designate those organic matters which contain the element nitrogen as an essential constituent. Not all organic matters contain this element, but the tissues of living things all contain or in part consist of, organic matters of which nitrogen is an essential element. Such matters as the substance or flesh, the proteate bodies, stirred up in the seeds of plants known as gluten and so on, and other substances contained in the juices and secretions of living organisms, which are organic in character, and which contain nitrogen as an essential constituent. There are certain nitrogenous organic matters secreted by plants and animals of which the best example perhaps is, the urea excreted by animals in the urine, which contribute in partial proportion to the nitrogenous organic matters contained in sewage.

Q. What is meant by the term "oxidation" used in the consideration of the organic matters in water?

A. By the term "oxidation" I mean the combining or uniting of oxygen with the various organic matters contained in the water, and in a general way also, the union of the elements of water possibly, with these organic matters which latter is frequently called hydrlosis. The effect of this oxidation being in general to convert the organic matters into substances which are regarded as inorganic or mineral in character.

Q. What agencies produce oxidation in water?

A. The chief agencies in bringing about oxidation of organic matters in sewage are the living organisms present in the water, particularly those of the minuter forms, and which are commonly referred to as bacteria.

5629 A. By the term "nitrification" as I have used it in my testimony I understand such oxidation of the nitrogenous organic matters contained in the water as results in the conver-

sion of the nitrogen of these matters into nitrite and nitrates; that is, essentially finally into saltpetre and nitre. Complete conversion of the nitrogenous organic matters that have undergone nitrification into mineral substances which comparatively are innocuous.

A. The turbidity of water is due to or consists in a certain appearance of cloudiness and partial opacity, which result from the water containing matters in suspension. The color of the water is distinguished from turbidity in that it results from the presence of colored matters in solution. A water may be quite clear and transparent, but have a decided color, and it may on the other hand be both turbid and colored. One is not necessarily associated with the other. Suspended matters which make a water turbid, may impart also a color to the water, but such color is removed by such filtration as takes out these suspended matters.

By total solids we mean all solid matters which are contained in solution and in suspension in the water, which matters are generally determined together as total solids, by evaporating a measured portion of the water to dryness, so that the water itself is expelled. The residue thus obtained is designated as the residue on evaporation or the total solids. By loss on ignition we mean the loss in weight which takes place when the total solids or residue on evaporation is gently ignited, that is, heated to dull redness, the loss resulting from this ignition is due to the partial burning away of organic matters, and to the loss of certain inorganic substances, and to the volatiliz-
5630 ation of certain inorganic substances or constituents of the residue. No very great significance attaches to the loss on ignition today for the reason that it is not practicable to distinguish accurately between such loss, as due to the destruction and removal of organic matters from the loss of inorganic constituents as water, carbon-di-oxide, oxygen from nitrates, salts of ammonia and so on. The significance attaching to the determination of total solids or residue on evaporation, lies in

the fact that too great a quantity of such matters contained in water render it unsuitable for domestic use or for manufacturing or steam making purposes.

Q. What does the presence of chlorine in water indicate?

A. Chlorine is contained in the soils in some proportion, but it is a considerable constituent of sewage and of manufacturing wastes. As contained in the water, it may be derived from one or all of these sources. The quantity contained in spring waters, is generally far less than the quantity contained in the waters of deep or artesian wells. The significance which attaches to the proportion of chlorine in the water, depends upon the source of the chlorine, the chlorine itself in such porportions as are found in ordinary waters is not objectionable. The proportion in sea water is so great as to render such water unfit for domestic use. The proportions of chlorine contained in the water of many deep wells is so great as to render the water saline in taste, and to render such water unfit for use for drinking or industrial purposes. It is to be understood in my statements covering chlorine, that it is chlorine in combination with basic matters and not the free substances or element that is referred to, as existing in these waters, that is, in general, it is in the form of sodium chloride, otherwise known as common salt.

Q. Does the presence of chlorine indicate at times the presence of sewage, or might it not indicate the fact that sewage has previously existed, but has now departed?

A. The presence of chlorides in the water is frequently an index to the quantity of sewage that the water does or has contained, but no inference concerning the quantity of sewage contained in the water can be had from a determination of the quantity of chlorine, the chlorides contained, unless other information regarding the water in question previous and
5631 subsequent to the introduction of the sewage, is in hand.

A. By the term "oxygen consumed" we mean the quantity of oxygen that the subtsances contained in the water absorb

or unite with in the chemical process used in making this determination. The quantity of oxygen consumed is an index to the quantity of organic matters contained in the water, and affords information concerning the character or, I might say, in some measure affords information concerning the character of the organic matters contained, that is, some organic matters required more, or combined with more oxygen under conditions of the determination that do others. If a considerable quantity of oxygen is required or consumed by the substances contained in a given water, the reasonable inference is that a considerable quantity of organic matters is contained. If on the other hand a small quantity of oxygen is required or consumed by the substances in a given water, the reasonable inference is that the quantity of organic matters contained in that water is correspondingly small.

In my testimony I have already stated what is meant by the term "nitrogenous organic matter." The term "total organic nitrogen" designates the nitrogen contained in combination in the nitrogenous organic matters. It is determined by the Kjel Dahl process, described in my testimony with reference to methods of analysis, and is to be distinguished from the nitrogen contained in the form of free ammonia, that contained in the form of nitrites, and that contained in the form of nitrates which are regarded as nitrogenous substances, and is also to be distinguished from that designated as nitrogen as albuminoid ammonia, although it includes the nitrogen of the latter. It is usually from two to three times greater than the nitrogen as albuminoid ammonia so-called. The nitrogen as albuminoid ammonia is derived from the substances which are designated as nitrogenous organic matter, but the nitrogen which, in the process of chemical examination, is determined under the name of nitrogen as albuminoid ammonia is only part of the nitrogen contained in the organic matters.

5632

Nitrogen as free or saline ammonia as recorded in the results of the sanitary chemical water analyses, is the quantity of

nitrogen contained in the water in the salts of ammonia or possibly as free ammonia, and as contained in water, is derived from various sources. The rain in falling through the air washes from it small quantities of nitrogen in the form of ammonia, or ammonia salts, and at times the proportion of ammonia and ammonia salts so introduced into water, may be considerable.

It is also derived from the soil or earth with which water comes in contact on its way to the streams, and is derived also from waste organic matters either of vegetable or of animal origin which may be upon or in the soil and earth with which the waters on their way to the streams in times of fall of rain or the melting of snows, come in contact.

It is also derived from the decomposition of various nitrogenous organic matters which I have described above, both those which are contained in the vegetation, that is, the leaves and stems of grasses, and other plants; of trees, waste vegetable products and waste animal matters of various descriptions,
5633 and also from the nitrogenous organic matters contained in sewage and in manufacturing wastes of various descriptions.

It is also produced at times by the reduction of nitrites when these are in contact with decomposing organic matters, when these all are wet or contained in water. The significance which attaches to the presence of free ammonia in a water depends upon the source from which it has been derived. The ammonia in itself in the proportions in which it is contained in waters is not objectionable, but inasmuch as the free or saline ammonia is a considerable constituent of sewage, the conditions under which it is introduced into or produced in or continues to exist in a given water, must be fully understood and considered in determining its significance in the particular case.

Nitrogen as nitrites as recorded in the results of the sanitary chemical water analyses refer to the nitrogen contained in combination with oxygen and other substances and constituting

salts, which are called nitrites. They are derived in part from the air, being washed from the air usually in the form of nitrites of ammonia by falling rain. They are also derived from the leechings of soils and earth strata with which the fallen rain on its way to the streams comes in contact. They are formed, moreover, in the oxidation of the various nitrogenous organic matters which have been referred to above in my testimony, both those lying upon the surface of the ground or contained in surface soils, in the streets, in barn-yards, in the fields, and from similar changes taking place in the nitrogenous organic matters contained in the water of streams and lakes and ponds; both those derived from or contained in nitrogenous vegetable matters of all descriptions and nitrogenous animal matters, such as are contained in the wastes of habitation, including sewage, barnyard wastes and various manufacturing wastes.

They are also formed by the oxidation of the free or saline ammonia above referred to, as well as by the reduction of nitrates.

The significance of the proportion of nitrites contained in a water depends upon the origin and the amount of the
5634 nitrites and the conditions prevailing at the place and time and in the body of water in which they are found.

Nitrogen as nitrates, as recorded in the results of the sanitary chemical analyses of water, represents the quantity of nitrogen that is in combination with basic matters and oxygen, the latter in greater proportion than is contained in the nitrites above referred to. The nitrates, like free ammonia, and nitrites are at times derived in part from the air, being washed from the air by rain and so carried to the earth. They are derived also from the earth strata with which the rain comes in contact and over which or through which it flows on its way to the streams or into the great body of ground water.

The nitrates are derived from the oxidation of the nitrogenous organic mtaters repeatedly referred to in my testimony above, to the oxidation of free ammonia and to the oxidation of

nitrites, both in soil strata and in the water itself. The nitrates constitute the chief final nitrogen containing product of the oxidation of nitrogenous matters of various descriptions, including the nitrogenous organic matters.

A portion of the nitrogen contained in all these various nitrogenous matters, organic and inorganic, is often separated in the form of free nitrogen gas, which may remain in solution in the water or escape from the water and mingle with the air, but generally the major part of the nitrogen of the various nitrogenous matters above referred to is oxidized finally to nitrates.

Nitrates are genarally found in notable quantity in the waters of wells, of considerable depth, the so-called shallow wells, and is frequently found in the water of deep wells. It is commonly found in the waters of springs, and is rarely, if at all, absent from surface waters.

It is formed in the oxidation of all sorts of nitrogenous organic matters, both those which are derived from natural vegetation and animal matters, as also from the wastes of habitation, including barnyard refuse, street washings, sewage, and so on.

The significance of the nitrates contained in water depends upon the source and quantity of the nitrates and the conditions under which it has been introduced into or produced in and continues to exist in, the given water.

5635 It is to be noted that the nitrogen passes through a series of conditions, or a cycle of transformations the starting point in which may be regarded as any one of the stages or any one of the conditions or combinations described above, in which it exists in waters. If we consider the nitrogenous organic matters as the first condition or combination in which the nitrogen exists, we may consider the nitrogen in the form of free ammonia as marking the next step or stage in the cycle, this free ammonia being produced in the decomposition or the breaking down of the nitrogenous organic matters, the result of this decomposition being to bring the nitrogen into a sort of combina-

tion, namely, the free or saline ammonia, which in the proportions found in water, is not in itself injurious or objectionable.

Following upon the transformation of the nitrogenous organic matters, and the conversion of the nitrogen from organic combination to the inorganic form of free or saline ammonia, the next step in the stage or cycle may be regarded as the partial oxidation of the free ammonia into nitrites which thus constitute the second stage in the series of transformations. The nitrites in turn by further oxidation are converted into nitrates, a comparatively stable form of combination usually regarded as the final stage of oxidation of nitrogenous matters, but the nitrates are utilized by living organisms, that is, plant life, as a food stuff, and the nitrogen of the nitrates built up into the substance of the plant, that is, converted again into the tissues, and so on, thus being converted into the nitrogenous organic substances of the plant, which nitrogenous organic substances either directly or after digestion and assimilation by animals and conversion into the tissues and secretions of animals may, when in contact with or contained in waters, enter again upon the same series of transformation we have just briefly discussed.

Q. Professor, is it possible to form a reasonably accurate judgment of the condition of a given water from consideration of any one constituent determined in the sanitary chemical analysis?

A. No reasonably fair judgment regarding the sanitary condition or the potability of a water can ordinarily be drawn from the consideration of any one single constituent determined in the sanitary chemical analysis of a water, but all must be considered together, and with full knowledge of the source of the water, and of the substances contained in it, and the conditions of time and place and environment, season, and so on.

5637 The fact as set forth in my testimony of this morning, relating to the mean monthly flow of water in the Illinois river at Kampsville during the years 1897 to 1902, inclusive, which showed that at times during the later period, that is, the

three years after the opening of the sanitary canal, or Chicago main drainage channel, a smaller volume of water was discharged than was discharged at times during the earlier period, and that the mean or average daily flow during the three
5638 years subsequent to the opening of the sanitary canal was slightly less than the mean daily flow during the three years period prior thereto, was due to the fact that in the years 1897 and 1898, the rainfall was considerably greater than it was during the years 1900 and 1901.

The year 1899 was a year of drought and the rainfall during that year was deficient, that is, below the normal, and the flow in the river at Kampsville was very considerably less than it had been during the years 1898 and 1897. In the following year, the year 1900, the drought continued, but there was increased flow in the Illinois river at Kampsville due to the increased discharge of liquid, that is, water and sewage, from Chicago through the Illinois and Michigan canal and the main drainage channel.

The year 1901 was a year of severe drought, deficient rain fall, high temperature and dry winds, and the flow in the river during this year was practically the same as the flow during the year 1899, the year immediately prior to the opening of the main drainage channel. On the other hand, the year 1902 was a year of exceptionally great flow, that is, the greatest flow during the six years here in question was that for the year 1902.

The average for the three year period, because of these variations in the rainfall for the various years was, on the whole a little less than the average for the three years prior to the opening of the main drainage channel.

Touching the questions at issue in this case, the real value of the evidence which I have introduced in this case in the way of analytical data lies in the comparison which it institutes between the period prior to the opening of the Chicago main drainage channel and the period subsequent to that opening. For the reason that the various determinations so far as they them-

selves were concerned, and including the collections of the samples, were made under precisely the same conditions throughout both periods, and that they afford data which are strictly comparable, and which show the conditions prevailing in the waters of the streams in question before and after
5639 the great change which was coincident with and produced by the opening of the Chicago main drainage channel.

The conditions which prevail at the mouth of the Illinois river at Grafton are such that at times water from the Mississippi backs up into the Illinois, and fluctuations in the height of the water in the Mississippi, and indeed, in the Missouri, produce fluctuations in the Illinois below Grafton. For these reasons, and because it was practicable to secure the services of most intelligent collectors, namely, the Assistant United States Engineers who were in charge of the improvements on the lower Illinois, and in residence at the Kampsville dam, Kampsville is the best place on the lower Illinois, near the mouth, to obtain, samples which should truly represent the character of the water of the Illinois river as it is about to discharge into the Mississippi.

5640 I have lived upon the watershed of the Illinois river for about 36 years. During a portion of that time living on the banks of the Fox river, one of the chief tributaries of the upper Illinois, and I have been fairly familiar with the conditions prevailing upon the watershed of the Illinois river and with the conditions along the stream itself during the last ten years, and am familiar with the conditions prevailing along that stream and upon much of its watershed today.

Taking into consideration my knowledge and information concerning the Illinois river, its tributaries, its watershed, and the conditions prevailing upon and along the same, and taking into consideration the chemical examinations that I have made of the waters of the stream and its various tributaries, both before and after the opening of the Chicago main drainage channel, it is my opinion that the effect of the greater dis-

charge of water resulting from the operation of the Chicago main drainage channel, has greatly improved the condition of the water of the Illinois river all along its course, rendering its waters less offensive to the senses in the immediate neighborhood of the point of discharge of Chicago's sewage into the Des Plaines and thence into the Illinois, and reducing the proportions of the organic matters contained in the waters of
5641 this stream at Averyville and at other points along its course, and reducing the proportions of nitrogen as free ammonia and as nitrates, and reducing also the quantities of nitrogen as ammonia and as nitrites contained in these waters, and in reducing not simply the proportions, but reducing also the actual quantities of the nitrogenous organic matters contained in the waters of this stream at various points, and particularly at Averyville, to all of which I have testified heretofore, in the evidence I have presented in this case; and with respect to Kampsville I may refer to my testimony given above in this case, and state it as my opinion here, based upon the considerations enumerated above, that the condition of the water at Kampsville has been greatly improved co-incident with and as a consequence of the operation of the Chicago main drainage channel, in that my evidence shows a great reduction in both the proportions and the actual quantities of the most significant constituents of these waters as determined by the sanitary chemical analyses. And I base this opinion further upon the fact that since the opening of the Chicago main drainage channel, or sanitary canal, although the quantities of organic matters in the sewage now discharged into the Des Plaines and thence into the Illinois river, are 30 per cent greater than before that opening, the proportions of organic matters contained in the waters discharged by the Illinois river into the Mississippi are considerably smaller than they were prior to 1900; and that this decrease of the proportions is not a mere dilution is shown by the fact testified to by me, that the actual quantities of organic matters discharged are now less than they were formerly. I have visited

the mouth of the Illinois river, the mouth of the Missouri river and the Chain of Rocks in the Mississippi river repeatedly and am somewhat familiar with the state of affairs there.

5642 From a consideration of my knowledge and information concerning these bodies of water, and a consideration of the results of investigations I have made of these waters, and the study of investigations made by others of these same waters, it is my opinion that neither the water of the Illinois river at its mouth, nor that of the Mississippi river just above the mouth of the Illinois river, nor that of the Missouri river just above its mouth, is suitable for domestic use; that is, particularly for drinking purposes without filtering, or without such treatment as shall render it sterile as by boiling or other means.

5643 From the knowledge and information which I possess concerning the waters of the Illinois river and the watershed of that river, the drainage canal and the Des Plaines river, and the conditions existing in and about them, and the results of the investigations which I have made of these waters before and after the opening of the Chicago main drainage channel and the knowledge I have of investigations of these same waters made by others before and after the opening of the Chicago main drainage channel, it is my opinion that the effect of the increased flow secured by the opening of the Chicago main drainage channel has been at times to increase the flow of water in the Mississippi river along the western borders of the State of Illinois and the eastern borders of the State of Missouri, and further it is my opinion that the increased flow secured by the opening of the Chicago main drainage channel containing as it does, increased quantities of organic matters derived from Chicago sewage, does not injuriously affect the waters of the Mississippi along the eastern borders of the State of Missouri so far as the use of such waters for domestic, agricultural and manufacturing purposes is concerned, for the reason that the effect of the increased flow secured by the opening of the Chicago main drainage channel, has been co-incident with

or the cause of more complete destruction of the organic matters introduced into the upper Illinois river to such an extent that the waters discharged by the Illinois at its mouth contain less organic matters than they did prior to the opening of the Chicago main drainage channel, and further for the reason that it is my opinion that the organic matters contained in the Chicago sewage conveyed into the Illinois river by the Illinois and Michigan canal and the Chicago main drainage channel, so far as the sanitary chemical analysis can determine, are destroyed compietely or converted into mineral matters and vegetable matter, which as contained in such water are practically innocuous.

5644 CROSS-EXAMINATION, by Mr. Jeffries:

5645 It is my opinion that the analyses which I have made of the waters of the streams of Illinois and to which I have testified in this case throw much light upon the sanitary condition of the waters in these streams but do not directly determine the question as to the presence or absence of disease producing organisms in said waters. My sanitary chemical analyses of the waters of the Illinois and Michigan canal, and of the Chicago main drainage canal were not such as might be expected to determine directly the presence or absence of disease producing organisms, but inasmuch as they were of such a character as to show the presence or absence of sewage, they do indicate the possible presence or absence of substances characteristic of sewage and hence, in some measure, disclose the pres-

5646 ence or absence of deleterious substances, substances which as a class are objectionable in drinking waters, for the reason that they themselves, or substances which accompany them in sewage, are deleterious to health when introduced into the system through drink. It is my opinion that the basis for the detection of the presence and the kind and characteristics of the disease producing organisms and subatsnces which in sewage and waters at times accompany the chemical constituents

found in these fluids, rests mainly upon the various chemical reactions and decompositions which said organisms and substances produce and the chemical substances which result from their action. The sanitary chemical analyses which I have made of these waters do not directly indicate the presence or

5647 absence of disease producing substances, and I have not determined directly the presence or absence of said disease producing substances in these waters.

5648 As a chemist and individual, it is my opinion that there can be no doubt but that disease producing organisms and substances are contained in sewage, and in sewage are frequently introduced into running streams.

5649 A chemist who concerns himself with the study of running waters, their pollution and purification, the seasonal variations to which they are subject, as to content and character of various substances does recognize the fact that disease producing organisms and substances are introduced into running waters in sewage and recognizes as a fact that the quantities of such disease producing substances and organisms may be greater or less at different points and at different times, although he, as a chemist simply, does not ordinarily determine the quantities of such disease producing organisms or substances. As a chemist pure and simple, one cannot determine the quantities nor their presence. There is nothing in the sanitary chemical analyses of water, as ordinarily conducted which discloses the kinds and character of the disease producing substances and organisms contained in polluted water.

5650 It is my opinion as a chemist and an individual, that the substances, the presence and proportions of which are shown by the sanitary chemical analyses of waters as ordinarily conducted, include those substances which serve as the food supply of micro-organisms, and include the substance itself of micro-organisms, both the harmless sort and the disease producing sort. (Witness is interrogated as to what a sanitary

chemical analysis of water may and may not determine.

5654 The nitrogenous organic matters in the water would most likely contain the disease producing organisms, if such a determination could be made. I have on several occasions found greater proportions of organic nitrogen in samples of water taken other than from Lake Michigan at the places heretofore testified to by me, then I have found in numerous samples of water taken from the Illinois river at Kampsville.

5655 In general the waters of Lake Michigan analyzed by me contained considerably less total organic nitrogen than I found in the waters of the Illinois river at Kampsville. Whether the organic nitrogen contained in the water of Lake Michigan analyzed by me, did or did not contain the micro-organisms which produce typhoid fever, I do not know, but assuming it to have been present therein, it is my opinion that there is nothing in my sanitary chemical analysis of the waters of the Illinois river at Kampsville which has determined whether or not a bacillus of typhoid fever was contained in that water.

5659 It is my opinion that my analyses give as complete evidence concerning the composition of all the waters passing the points at which samples of said water were collected, so far as it is possible by a sanitary chemical analysis to do so, for the reason that it is not practicable to analyze at any time much less at all times, all the water flowing past a given point in a stream, of such a stream as the Illinois and other streams referred to in my testimony introduced in this case; and

5660 I will add further that while it is always desirable to have as many analyses as is possible, and even more than the number which I made for, say the point on the Illinois river at Kampsville, practical reasons, that is, those involved in the time, labor and expense, have prevented my making more analyses of the waters at the given points during the periods covered in my testimony, and it is my opinion that the evidence

which I have submitted covers the case reasonably well, and as well as similar cases have been covered at other places and by other people in the examination of the waters of running streams.

It is my opinion that the water of the Illinois river at Kampsville has not been at other times during the period in question materially different from the condition revealed by the analyses which I have submitted in evidence, and it is further my opinion that the data which I have submitted reveal substantially the true composition of the water of the Illinois river at this point, namely, Kampsville, during the entire period covered by the analyses, namely, the years 1897 to 1902 inclusive.

5663 (Witness explains the variations between results shown by tables introduced by himself and those introduced by Prof. Bisbee.

5665 In my opinion, these variations in the results of the
5666 analyses do not indicate similarly considerable variations in the actual content of the total organic nitrogen in the water samples collected at the same date and hour, nor do they show rapid variations in these substances contained in the water, but in my opinion the variations in the determinations as recorded in the tables you have quoted, are very largely the result of differences in the details of the method employed in making these determinations to which I have referred in my answer to the preceding question.

These variations between the analyses made by Prof. Bisbee and myself, doubtless are in part due to differences in accuracies and differences in inaccuracies, but in my opinion, in the main, they are due to variations in the details of the processes employed in making the determinations. I have been told by mathematicians and physicists at times, that chemistry is not an exact science. Undoubtedly it is not in my opinion,

capable of such exactness as are the various processes of mathematics. It is my opinion that the averages based upon a
5667 given series of chemical determinations afford as accurate a basis for comparison and for determination of certain facts, as do the averages computed concerning the height of man, in the determination of the heights of man, or as the averages of the length of life of individual man, and of individuals of a certain class of men computed by the actuaries of insurance companies, which afford a substantially accurate basis for the determination of the length of life of individual man and classes of men, and thus afford a reasonably accurate basis for conducting the business of life insurance.

If we were to assume that there were no inaccuracies in
5669 the details of the methods employed in making the determination of the total organic nitrogen in these two samples collected at the same point, at the same time and analyzed, the one by Mr. Bisbee, the other by myself, then the results of said analyses would indicate a difference in content of total organic nitrogen as between the two original samples, but as I have stated in my answers to the three or four preceeding questions, in my opinion, the variations in the details of the methods employed in making the determination of total organic nitrogen in these two cases is mainly accountable for the differences which appear in the record.

Q. Then what you have stated with reference to the variation between the analyses with reference to total organic nitrogen as determined by yourself on the 6th day of September, 1899, from the sample of water collected at Kampsville, as compared to a companion sample collected at the same time by the same collector, and analyzed by Professor Bisbee, which shows a variation of 40 per cent, the same answer is applicable to the sample collected on the 13th day of September which shows a variation of 23.8 per cent, is it not?

A. In my opinion it is.

The same is also true as to the other samples in which there is a variation between results obtained by me and those obtained by Professor Bisbee.

5671 (Witness states the variations in accuracy in the determination of the various analyses made in his laboratory.)

5678 I would further add that in my opinion the comparison of the data of individual analyses from the various series of analyses introduced by me as evidence in my testimony does not constitute a very important part of said testimony, but that the comparison which I have instituted between the averages for the individual years, and for the three year period prior to January, 1900, and the three year period subsequent to the first of January, 1900, rests upon a reasonably accurate basis in fact, and that these averages made up as they are from the data of analyses of samples collected at regular stated periods, namely once a week, throughout the six year period mentioned, afford a sound basis for a comparison of the condition of the waters in the Illinois river at Kampsville during the two periods in question.

5680 It is my opinion that high chlorides together with high nitrates result in a loss of a portion of the nitrogen contained originally in the water in combination with organic substances when organic nitrogen results are effected by the Kjeldahl process. (Witness is interrogated as to changes which may take place as to organic nitrogen, etc. in the samples during transportation from place of collection to the laboratory.)

5683 (Witness explains difference in method employed by Prof. Bisbee and himself in the determination of the various analyses made by them.)

5685 I made but three or four determinations of dissolved oxygen in the waters of the sanitary canal, but such as I have made did not reveal the absence of dissolved oxygen therefrom, and I have at no time found the waters of the Illinois river in its lower stretches wholly devoid of dissolved oxygen. However, in the water of the sanitary canal at the Bear Trap

dam on August 14, 1900, I found but 5.88 per cent saturation with dissolved oxygen and on June the 29th, at the same point, but 10.88 per cent saturation with dissolved oxygen.

Q. Is it possible for a septic operation to be going on in a water where analysis shows nitrogen in the form of nitrates?

A. With respect to that the only information which I have personally upon the subject is the result of examination of sewage entering, and the effluents proceeding from septic tanks which showed the presence at times of nitrates in the effluent of the septic tank, from which it may be inferred that a septic action going on within the tank, went on with the presence of nitrates.

It is in my opinion true, that a septic tank affords one of
5686 the best and quickest means of resolving the constituents of sewage into simpler and less noxious forms, but the action of the septic tank never completely resolves these matters into the simplest forms, and following upon the series of decompositions which it produces, there must, in order to bring about the oxidation of these products and their conversion into other sets of simpler forms, be a new or other series of agencies set in operation.

5692 In answer to a hypothetical question assuming that immediately after the opening of the canal the water in the Illinois river at Grafton, and the Mississippi river below Grafton and at the Chain of Rocks, assumed a black, sewage muddied condition at times, and asking what, if anything, the sanitary analytical examinations of the waters of those rivers and of the canal show, in reference to the presence of such polluting substances therein contained, witness stated that so far as the assumption of a black sewage muddied condition of the Illinois river water throughout its length, or at various points along it, and the same condition including Grafton and the Mississippi river between Grafton and the chain of rocks, is concerned, I would state as my opinion that such assumption is altogether beyond the fact, that no such condition was to my knowledge, observed along the course of the Illinois river, nor at Grafton,

nor in the Mississippi river between Grafton and the chain of rocks, but that on the other hand, the results of my analyses, particularly those having to do with the appearance and the odor of the water, indicate that no such condition maintained or held except that in the upper stretch of the Des Plaines river in the vicinity of Joliet, the odor of the water as recorded in table 44 of the series of analyses I have submitted, as gassy, from January 2d to March 26th, 1900, and that the water in the Illinois river at Morris, collected upon January 26, 1900, had an odor which is indicated as gassy. There is nothing else in the series of analyses included in my tables which indicates directly a more than usually large proportion of sewage contained in these waters. On the other hand the variations in color and in the proportions of suspended matters and in the color of the suspended matters contained in the water during this period, were not different from those observed in other years in like seasons.

I would further add that I obtained from the various collectors of water samples along the river, information concerning the appearance of the water at this time and in no case did they note an unusually dark or black sewage colored mud contained in the water. They failed to note anything particularly different from the usual appearance during the season of high water in the Illinois river, in the spring.

5694 Q. Professor, assuming that there is discharged into the Illinois river by means of the drainage canal, the sewage from the city of Chicago which contains certain organisms which produce typhoid fever; assuming that those organisms are of a living character and that they live in the sewage
5695 of Chicago the drainage canal and the waters of the Illinois river from five to thirty days or more, disappearing by death gradually at from five to thirty days or more until at the end of thirty days or more, all have become innocuous; assuming further that they flow down the canal to the Illinois river with the water and with the same velocity as the water in the canal and the river. Assume that the mean velocity from

Chicago to St. Louis is eighteen days; assume that the average life of these organisms has expired at some point between Averyville and Grafton, but assume also that as heretofore stated, the extreme life limits will carry them in thirty days or more to a point far below St. Louis. State whether or not a table of averages upon the life limit of these organisms, which shows that such average took place at some point in the river between Averyville and Grafton, can be used by a sanitarian, or by a sanitary chemist, as proof from a practical sanitary standpoint that no such disease producing organisms pass a given point between Averyville and Grafton and do not reach the St. Louis intake at the chain of rocks and pass beyond the city of St. Louis.

5697 A. It, in my opinion cannot, but the conditions prevailing in the Mississippi river between Grafton and the chain of rocks as to the mixing of the waters in the Illinois with the waters of the Mississippi and the waters of the Missouri, render it, in my opinion, highly improbable that any considerable proportion of such pathogenic germs as may be contained in the waters of the Illinois at Grafton,—that is, if we grant the assumptions of the question, passes down the Mississippi to the point below, St. Louis, and is taken into the intake of the St. Louis waterworks.

PROF. ARTHUR W. PALMER, resumed the stand for redirect examination by Judge Springer:

In my opinion there is evidence given by my analyses that septic action takes place in the waters of the drainage canal. My reasons for that are that the comparisons of the averages which appear in table D heretofore introduced in my testimony representing the analyses of the waters taken from the sanitary canal at Kedzie avenue at its Chicago end, and taken at Lockport at the Bear Trap dam, for the four summer months, June, July, August and September, 1900, show a series of changes of the organic matters which are of the same nature as the changes which take place during the passage of sewage through a septic

tank. (Objection by Mr. Jeffries, which objection is argued on pages 5698-9.)

5700 Thus the average proportion of the total oxygen consumed by the water collected from the sanitary canal at Kedzie avenue, was, for the four months in question, namely, June, July, August and September, 1900 8.9 parts per million, while the proportion contained in the waters collected at the Bear Trap dam during the same period was upon the average, 8.8 parts per million, showing a reduction of 1.1 per cent in the proportions of total oxygen consumed. The proportions of oxygen consumed by the dissolved substances in the water at Kedzie avenue, were 4.6 parts per million, while the proportion required by the water at the Bear Trap dam was 7 parts per million, showing an increase in the proportion of oxygen consumed by dissolved matters as between the samples collected at these two points on the drainage canal, of 52 per cent.

The proportion of oxygen required for suspended matters was, for the samples collected at Kedzie avenue 4.3 parts per million, while the proportion required by the waters collected at the Bear Trap dam were 1.8 parts per million, showing a reduction of 6 per cent.

The average proportions of free ammonia found in the waters at Kedzie avenue, were 1.174 parts per million, while the proportion found at the Bear Trap dam was 1.235 parts per million, showing an increase in the proportion of nitrogen as free ammonia of 5.2 per cent.

The nitrogen as albuminoid ammonia, that is the total for Kedzie avenue, was .45 parts per million, while the proportion found at the Bear Trap dam was .426 parts per million, a reduction of 5.3 per cent.

The proportion of nitrogen as albuminoid ammonia de-

5701 rived from dissolved substances was for the Kedzie avenue sample, .158 parts per million, and for the sample collected at the Bear Trap dam it was .218—showing an increase between these two points in the dissolved albuminous matters

in the proportion as against the nitrogen contained, of 38 per cent.

The nitrogen as albuminoid ammonia derived from suspended matters was, in the Kedzie avenue sample, .292 and for the samples at the Bear Trap dam, .208—showing a reduction between these two points of 28.7 per cent.

The total organic nitrogen for the Kedzie avenue samples was 1.047, and for the samples taken at the Bear Trap dam, it was .902, a reduction of 12.9 per cent.

The total organic nitrogen derived from dissolved matters was at Kedzie avenue, .365, and at the Bear Trap dam .435, an increase of 19 per cent.

The total organic nitrogen in suspended matters was, for the samples taken at Kedzie avenue, .682 parts per million, while the proportions found in the samples collected at the Bear Trap dam were .467 parts per million, showing a reduction of 31.5 per cent.

These changes, which occurred during the time of the passage of the water from the upper opening of, or the entrance to the Chicago main drainage channel, and the out-flow of these waters at the Bear Trap dam are similar to the changes that occur during the passage of sewage through a septic tank in this particular, that the proportion of free ammonia is increased, and that nitrogenous organic matters and other organic matters which were in suspension, have been taken into solution and thus brought into a condition which prepares it for the next process of purification, namely the oxidation which occurs as these waters mix with the waters of the Des Plaines and the Illinois, and flow on down the course of the Illinois river; that is particularly the oxidation of the organic matters and the nitrification of the same; these two sets of processes resulting in the destruction of much of the organic matter, part of it being converted into gases, the oxidation process producing mainly

carbon di-oxide and water, and from the nitrogen producing nitrites and nitrates.

5702 (Witness states to what he ascribes the fact mentioned in his testimony that no unusual appearance of black sewage muddied condition occurred in the waters of the Illinois river just after the opening of the drainage canal.)

5704 In reference to the limits of accuracy in the determination of the various substances disclosed by my analyses of the water in question, it is my opinion that the data of the analyses which I have read in evidence, and to which I have testified in this case substantially represent the sanitary chemical condition of the waters in the Illinois river at Kampsville during the entire periods covered by the series of examinations, and that in particular the comparison of the averages for the various years and for the two three year periods rest upon a substantial and sound basis.

RE-CROSS EXAMINATION, by Mr. Jeffries:

5705 In the absence of direct knowledge of the conditions prevailing in the bottom, near and in the mouth of the Chicago river, I can make no definite statement, but in a general way would state it is my opinion that in all probability, at times there is still septic action going on in the sediments in the bottom of the lake, in the vicinity of the mouth of the Chicago river.

5709 I have no doubt that at times the water before it leaves Lake Michigan and passes into the river is in an unsanitary condition.

5711 THOS. J. BURRILL, Examined in chief by Judge Springer:

Am a member of the faculty of the University of Illinois. I hold now the Professorship of Botany. Was educated at the Illinois State Normal University. I pursued a course largely for teachers and specialized as much as possible in biology. I

quit that institution in 1863. (Witness states his educational qualifications.)

5716 Beginning with May, 1899, I made a series of examinations from selected points in the course of the Illinois river and its tributaries, and these were conducted until October, 1900, and then in 1901, a series was made extending from October to December inclusive.

These were for the most part weekly collections, from the stations arranged for by Professors Palmer and Jordan.. There were two samples in each collection, and in the whole for the two years first named, there were 2800 of these samples; the number of entire cultures made from these samples amounted to about 7,000.

These examinations were upon samples taken under the direction of Prof. Palmer and Prof. Jordan and were procured at the times and places mentioned in the detailed reports of Streams Examinations by Prof. Palmer. The tables No. 1 to 80 inclusive, put in evidence by Prof. Palmer and published in the book known as "Streams Examinations, Sanitary District of Chicago," were made by Prof. Palmer and myself. (These tables are reproduced on pages 4939 to 5026 inclusive of this record.)

5717 The last two columns in each of the tables were made by me. The "+" sign, or an upright cross, is used to indicate the positive presence of the bacillus coli communis as determined by me. The horizontal line "—" commonly called the minus sign, is used to indicate, according to our tests, the absence of this organism and the interrogation point, "?" is used when the test could not be relied upon to indicate its presence, but did give some evidence of its being there. The small dots

indicate that for some reason no examination was made of the samples collected under those particular dates.

5718 Witness gives errata as to bacterial counts in tables No. 1 to 80.

5722 Table F, Streams Examination, Sanitary District of Chicago, Sanitary Water Analyses, Monthly Average of Colony Counts, Report of T. J. Burrill, contains the monthly averages of colony counts based upon tables 1 to 80, to which I have referred, subject to one difference. This table of averages was based on the regular weekly collections from the streams. When there were any extra collections, as there were at Grafton and at the Chain of Rocks and other places sometimes, those extra collections were not included in these averages. Said table offered in evidence and reproduced on pages 5724 and 5725.

5726 (Witness states method of plating for these colony counts.)

5728 (Witness explains method of determining presence or absence of the bacillus coli communis and refers to two photographs giving conditions for one week's tests, which photographs were marked Defendant's Exhibits D and E for identification to be incorporated in the testimony hereafter if counsel on either side so desires.)

A. The difference in colony counts for different portions of the stream is very marked, and while there is considerable variation for each point, there is for all of our tests very striking agreement in the greater number existing in the course of the stream near its head at Bridgeport, amounting to several millions a cubic centimeter, and then a more or less gradual decrease to Peoria, and from Ottawa to Peoria, this decreased number is exceedingly marked.

Q. Please point out the differences which are indicated between the colony counts at Bridgeport and Averyville, for the period in question?

A. The colony counts from the tests made from samples taken at Bridgeport on November 7, 1899, were 4,790,000;

November 15th, 1,960,000; November 21st, 3,920,000; November 29th, 315,000, with the average for the four tests of 2,497,000.

At Averville for the same time, the counts were respectively, 550, 1,100; 1,200; 2,800; an average for the four tests, 1,640.

Q. For the year 1900 what do those counts show for these two places?

A. And for the year 1900 in April at Bridgeport, on the 3rd of that month, 5,300,000; on the 10th, 3,725,000; on the 17th, 11,200,000; on the 25th, 3,925,000, with an average for the four tests of 6,037,500.

While at Averyville for the same times, the counts were 28,000; 17,000; 5,500; 1,850; and with an average for the four of 13,087.

The colony counts showed a great increase in number of bacteria after the pollutions were received by the river from Peoria and Pekin. As an illustration of this I will say that in 1899 on November 1st, there were found at Pekin, 2,780,000 bacteria per cubic centimeter; on November the 9th, 170,000; on November 16th, 145,000; on November 24th, 95,000; with an average for the four tests of 797,500.

3730 For the same times at Beardstown, which is 56 miles further down stream, the colony counts were respectively 6,500; 21,500; 7,150; 35,200, with an average for the four tests of 17,590 for the year 1900. For July 6, 1900, there were at Pekin 38,500; for July 12th, 555,000; July 19, 370,000; July 26th, 220,000; with an average of 295,875. While at Beardstown for the same times there were respectively 3,500; 4,000; 3,000; 3,600, with an average of 3,700. I should say that in order to make this tabular statement, the dates given sometimes vary by one day, for one or the other of the numbers given, because the collection was not always made on the same day.

The averages in the last figures show respectively, 45 and 71 times as many bacteria in the water at Pekin as at Beardstown, though the distance is 56 miles and the time required for the flow of water 24 hours. I prepared graphic plates based

on the data contained in monthly averages exhibited in table F of the data contained in tables No. 1 to 80 of the series in question. These plates are known as plates XXI to XXVIII of the Bacteriological Laboratory of the University of Illinois.

Plate XXI is reproduced on insertion facing page 5730.

5731 The earlier tests (those from samples taken above Ottawa) were not indicated on this plate because the numbers are so great that they could not be shown on this scale. It will be noticed that at Ottawa the number was 20,000; at La Salle it was about 18,000; at Henry it was about 64,000; at Averyville it was about 9,000; at Wesley City the number was so great that it could not be shown on the plate. The lines were stopped near the upper part of the plate and the number inserted, 1,476,480. And at Pekin for the same reason the line does not show the number, but the figure is put in 1,500,000. Now the number drops quickly to Havana, where it is shown to be about 8,000; at Beardstown about 5,000; and at Kampsville about 6,000; and at Grafton about 5,000 again. At Alton about 6,000; and at Mitchell as named on this plate, about 17,000.

It ought to be said that the term "Mitchell" is used here as the nearest railroad station to the place otherwise called the Chain of Rocks. Now for June in the year 1900, at Ottawa, the number is about 14,000; something a little less at LaSalle, and 3,000 at Henry, and 1,500 at Averyville, all of which is below that of 1899, and then at Wesley City, six miles below Averyville and below the reception of the Peoria sewage, 59,000 and at Pekin, 150,625; and at Havana, about 15,000. At Beardstown, 8,000; at Kampsville, 2,000; at Grafton, Illinois river about 7,000; and at Alton, 8,000; and at Mitchell, 21,000.

I wish to say that the showing is for 1900, less than for 1899 in the first part of the stream as here indicated, and more for some distance after Havana, less at Kampsville and more again at Grafton, Alton and Mitchell.

5732 There is further shown on this plate the colony counts for the Mississippi river at Grafton, by a little separate circle, showing about 5,000 for 1899, and 3,000 for 1900; that is,

the showing for the Mississippi during this comparison is a little lower in each case than for the Illinois river. Plate XXII shows the same thing as plate XXI but represented in a different way and has in addition the showing for the Illinois and Michigan canal at Lockport; for the Des Plaines river at Joliet, and for the Illinois river at Morris. In Plate XXI the presentation is shown by oblique lines; in plate XXII, the exhibit is made by perpendicular lines. Plate XXII is reproduced on page 5734.

5735 Plate 23 shows the average number of bacteria per cubic centimeter as determined by the tests during July, in 1899, and also for the same months in 1900. The solid black line, exhibits the number for 1899, and the broken line for 1900 of this month.

It will be seen that for the year 1899 we started Ottawa with about 9,000 bacteria. At LaSalle the number sinks to about 7,000, at Henry it rises again to about 22,000; at Averyville it is a little over 9,000; and at Wesley City the line, if drawn would extend beyond the plate, and the figures are given to indicate 3,925,000, and at Pekin, 737,625. At Havana the number rapidly decreases to about 6,000 and at Beardstown to about 1,000. Again at Kampsville it rises somewhat, to about 3,000; slightly sinks again at Grafton, to about 2,500, for the Illinois river, and at Alton to something less than 2,000, while at Mitchell it rises to about 6,000.

For July, 1900, we have commencing at Ottawa, from 2,000 to 3,000; at LaSalle, 3,000 to 4,000; at Henry, 40,000; at Averyville about 4,000; at Wesley City, about 96,000; at Pekin 313,375; and at Havana 23,000; at Beardstown about 4,500; at

Kampsville 2,000; at Grafton about 4,000; at Alton about 6,000 and at Mitchell 26,000.

5736 Plat XXIII is reproduced facing page 5736.

Plate XXIV is another way of showing what was con-
5737 tained in plate 23, and with the addition of the exhibit for the Illinois and Michigan canal at Lockport, for the sanitary canal at Lockport, for the Des Plaines river at Joliet; and for the Illinois river at Morris. In this plate the indication is made by vertical lines, with the black solid lines for 1899 and the open light lines for 1900.

The line for July, 1899 at Lockport, Illinois and Michigan canal, shows about 5,320,000 and for the same month in 1900, 740,000; for the Des Plaines river at Joliet, for 1899, 2,850,000; for 1900, 170,000; Morris for 1899, 930,000; for 1900, a little less than 45,000. At Averyville, the exhibit shows very few numbers for both years, about 10,000 for 1899 and rather less than 5,000 for 1900. For Wesley City, for 1899, 3,925,000; for 1900, a little less than 100,000; at Pekin, for 1899, 740,000; for 1900, 315,000.

5738 From Havana on through the course of the stream, the indications show very clearly that the number of bacteria were, compared with those already mentioned, exceedingly small. Plate XXIV is reproduced on page 5739.

5740 Plate XXV shows the average number of bacteria per cubic centimeter of the water tested during August, 1899, and for the same month, 1900, from Ottawa to Mitchell.

Plate XXVI gives the same exhibit as that for plate XXV, but in plate XXVI the indications are by vertical lines, the solid black line for 1899, and the open or lighter line for 1900, and with the addition of the exhibit for the Illinois and Michigan canal at Lockport; sanitary canal at Lockport; Des Plaines river at Joliet, and the Illinois river at Morris.

Here again the line for 1899 for the Illinois and Michigan canal at Lockport show that the number of bacteria were very much greater for the same waters than for the same place in

1900; that for 1899, indicating about 3,240,000; and for 1900, 790,000.

5741 Q. The counts which are indicated thereafter beginning with Havana, and ending with Mitchell, show what condition?

A. Here again it is indicated that the comparative number of bacteria found is very much less than at Wesley City and at Pekin, but upon the whole, very similar to those found from Ottawa to Averyville. The largest number represented in this section of the plate, that is, from Havana to Mitchell inclusive, was, in the Missouri river at West Alton, in 1899. The showing is not far different in this part of the plate, otherwise than as mentioned, between the two years.

Plates XXV and XXVI are reproduced on pages 5443-5.

5744 Q. I call your attention now to plates XXVII and XXVIII of this series. What are represented by these plates?

A. Plate XXVII shows in a graphical way the average number of bacteria found at the collections taken from Ottawa to Mitchell in September, 1899 and 1900; and plate No. XXVIII is an exhibit of the same in vertical lines, with the addition of the showing for the Illinois and Michigan canal at Lockport, the sanitary canal at Lockport, the Des Plaines river at Joliet, and the Illinois river at Morris. Reproduced on page 5746.

5748 These tables present in a graphical way the very great difference in the number of colonies of bacteria found on our test plates made from water taken at these different places. It will be seen that without exception these numbers are very large, from the waters taken from the Illinois and Michigan canal at Lockport, from the sanitary canal at Lockport; from the Des Plaines river at Joliet, throughout the time that the examination was made. At Morris also the plates show that the number was very large, yet a considerable decrease from those at the places just mentioned, in most cases, though in the showing for August, 1899, the number is nearly as large as we find it to be at any of the places. This indicates to me

that the waters through this course of the stream, have in them great quantities of decomposable organic matter suitable for food for these organisms, and that the other conditions are such that the latter multiply enormously in these waters; but between Morris and Ottawa the indications are from these plates, that a great change takes place; that the numbers of bacteria are greatly increased. The decrease is out of all proportion to the increase of water received by the stream during this time, or in other words, the amount of dilution that the stream has after passing Morris. This decrease in the number is maintained with some irregularity to Averyville, where the number found on an average, equals that of ordinary river water, not especially subject to contamination. This seems to be true in every case, as shown by these plates for the condition of things in the Illinois river at Averyville.

This showing seems to prove that the pollution of the water at Bridgeport, and subsequently near the head waters, has practically disappeared at Averyville.

The plates taken together show very conclusively great
5749 pollution of the stream below Averyville, but that the organic matter is largely absent in the course of the stream after it reaches Havana, and especially so at the mouth of the Illinois at Grafton.

There is practically no difference so far as shown by these plates, in the waters of the Illinois river before they enter the Mississippi river at Grafton, and of the Mississippi river above the mouth of the Illinois river at this place. There is, however, a continuous exhibit of a greater number of bacteria in the waters of the Missouri river at West Alton than there are in either the Illinois river or the Mississippi river at Grafton.

Q. What conclusion do you draw from this difference?

A. I can only infer that the waters of the Missouri river at West Alton have in them greater contamination than have the waters of the Illinois river and the Mississippi river at Grafton. I do not think I have enough information of the special reasons for the conditions as shown for the waters of the

Missouri river at West Alton to be able to say why the pollution is greater there than in the Illinois and Mississippi at Grafton. I will say, however, that the records of temperature in these waters show that those of the Missouri are for the most part somewhat lower than are those for the Illinois and the Mississippi. This lower temperature probably has something to do with the lessened rate of decrease in these colder waters, than in the warmer ones, for it must be understood that the waters which have a temperature favorable to the growth and multiplication of bacteria, clear up sooner than those not so favorably conditioned.

I would like to express my opinion, that the greater part of this clearing up from the pollution of the water is directly due to the agency of the bacteria themselves, and this will explain why I say that the more favorable the condition for the growth and multiplication of the bacteria the quicker the pollution disappears.

5750 The bacteria have in general, as a source of food, dead organic matter. They in this respect have the same influence upon this organic matter as do animals, reducing the compounds from their higher or complicated states to less and less complex conditions, until finally the hydro-carbons are so reduced to water and carbon dioxide and the proteid matters, to ammonia or still further, to nitrites and nitrates ultimately; in other words, the principal role of bacteria in this regard is exactly opposite to that of green vegetation,—the latter are concerned in building up organic compounds from the simpler states, and the bacteria are reversing the process and ultimately the result is that the operations of the green vegetation are exactly destroyed; and we start over again with the condition of the substances in which we had them at first.

5752 Sewage is richer food for bacteria than any other that commonly escapes into our river water courses from the land, or from the surface of the earth otherwise. There is rarely found such very large numbers of organisms in river

waters except from sewage contamination, and I mean by this when the numbers run into the millions per cubic centimeter.

When, in the examination of water at different points in a river, I discover a material reduction in the number of micro-organisms I think I am entitled to infer that the matter suitable for food for these bacteria has disappeared, and since, as has just been said, sewage is the richest food commonly in such water, I may further infer that the sewage has disappeared. Plate XXIX and XXX being identifications of bacillus coli communis in the Illinois and Mississippi rivers and tributary streams, are reproduced on page 5754.

5755 Witness reads from these plates and states that this indicates that the organism is most often present in the
5756 waters of the Missouri river; next in those of the Illinois at the mouth and somewhat less frequently in those of the Mississippi, if we take into consideration the whole time of the investigation.

By reference to the graphical showing in this connection it will be seen that the less number of positive results through the whole course of the stream from Bridgeport to Mitchell was at Averyville, there being a slightly greater per centage of positive results at Grafton than at this last place. The greater number shown for the waters collected near Mitchell, seem to be due to the larger proportion or greater number in the waters of the Missouri river.

5759 In my opinion the very decided reduction of the number of the bacteria found in the course of the stream up to the time the waters reached Averyville, causing the waters at this place to assume the character of a normal river water, indicates that the contaminations from the sewage introduced into the stream from Chicago have disappeared at this point, and I cannot otherwise than conclude that the evidence now presented shows that the water at the mouth of the Illinois river at Grafton is practically free from any such contaminations introduced at Chicago.

I find also that the contamination as indicated in the water at the inlet tower at the Chain of Rocks, has a larger portion of its contamination from the water of the Missouri river rather than from the combined waters of the Illinois and the Mississippi at this point. I can say that the opening of the drainage canal has had no effect upon the waters of the Mississippi river one way or the other.

I made bacterial examinations of the waters of the Illinois river, the Mississippi river and the Missouri river in the months of October, November and December, 1901.

5760 These examinations were conducted for an extension of the examinations made in the years 1899 and 1900 and for the same purposes so far as relates to the condition of the waters in the stream. I prepared tables which are intended to indicate the number of bacteria in a cubic centimeter, and the identifications of the bacillus coli communis in the weekly samples taken from the Illinois river at Averyville, at Pekin, at Grafton, and from the Mississippi river above the mouth of the Illinois at Grafton, and from the Chain of Rocks in the Mississippi river, and from the Missouri river at Fort Bellefontaine. The samples were collected under the direction of Prof. Palmer in the same way that they were made for the years 1899 and 1900 and were obtained from the express company at his laboratory, from which they were immediately removed to my laboratory on arrival. The said tables are reproduced on pages

5770 5761 to 5769 inclusive. I computed averages from the total tests made of the water collected at each place and also the percentage of positive results from all tests made for the bacillus coli communis in each case. Plate No. XXX 1-2 showing averages graphically indicated, based upon tables heretofore introduced in evidence, showing colony counts and the presence of the bacillus coli communis as found in samples of

water taken from the Illinois, Mississippi and Missouri rivers in 1901.

5772 This series of investigations shows very closely just what was presented in the series for 1899 and 1900, already presented, and gives clear evidence that the water from the stream of Averyville is comparatively pure, or at least

5773 free from great numbers of micro-organisms, and also quite commonly free from the bacillus coli communis. The percentages of total tests which were positive in this examination proved to be 6.2.

Q. That 6.2 per cent refers to the percentage of times that you found the bacillus coli communis?

A. Yes sir. If we compare this with the water taken from the Pekin station, we find a very great difference, and it shows local contamination, since there are an average of 299,000 bacteria to the cubic centimeter, and 7.6 per cent of positive tests for the bacillus coli communis.

This pollution at Pekin seems to have disappeared at the mouth of the Illinois river at Grafton, since the average number of colonies is 8,441, and the percentage of positive tests for bacillus coli communis is 10.7.

If we compare the results from the waters of the Illinois river near its mouth, with that of the Mississippi river above the mouth of the Illinois, we find the result in regard to the number of colony counts slightly in favor of the Mississippi river as was found in the previous case, the average here being 5,407. This difference between 5,407 and 8,441, may or may not show a constant condition of things, as the difference is too small for this purpose, but the tests in regard to these two waters made for the determination of bacillus coli communis, favor somewhat the Illinois river water as against the Mississippi river water, since the percentage in the former is 10.7 and in the latter 11.5.

At the Chain of Rocks, where four samples were each time taken across the stream, the indications are that the pollution increases from the Illinois shore to the Missouri shore, as this

series of counts show, namely, for the Illinois shore 52,177, for the midstream, 43,185; for the intake tower 127,862 and for the Missouri shore 32,845. This last is the only count which does not support the statement just made.

For the determination of bacillus coli communis in the same water we find beginning with the sample taken near the Illinois shore, 21.7 per cent; from midstream 50 per cent; from the intake tower 36.3 per cent; and from the Missouri shore 57 per cent.

5774 Comparing now these last result with those obtained from the waters of the Missouri river at Bellefontaine, or as it is sometimes called, West Alton, the indications are that this latter stream is considerably more contaminated, since the average number of bacteria per cubic centimeter is 127,353, and the percentage of positive tests for bacillus coli communis is 57.1.

This means, so far as this evidence can be taken to mean anything, that the waters at the intake tower are largely derived from those of the Missouri river, and to present this a little more clearly, the results of the examinations of the water from the Missouri at Bellefontaine and of those at the intake tower may be placed together. From the former, that is the Missouri, the average number of bacteria per cubic centimeter is 127,353; at the intake tower the average is 127,862. The percentage of positive tests for bacillus coli communis from the Missouri river is 57.1 per cent, and the intake tower 36.3 per cent.

The whole examination seems to indicate that the water which is comparatively pure at Averyville, becomes very greatly contaminated at Pekin, clears up again at Grafton, and at this point compares favorably with the waters of the Mississippi river above the mouth of the Illinois, and very favorably with those of the Missouri at Bellefontaine.

Q. What significance do you attach in running river water to the presence of bacillus coli communis?

A. The presence of this organism means to me more than

anything else, that the water is contaminated with sewage, and that this shows its bad quality for drinking purposes.

I will say that since bacillus coli communis, and bacillus typhosus is mainly derived so far as they are found at all in water, from the same source, that the very common presence of the former may be held to give some indication, though by no means a positive proof, of the presence of the latter.

Q. Did you have any difficulty in determining the presence of the bacillus coli communis in your examinations of the water?

A. I cannot say that we did.

Q. Professor, on day before yesterday, in your testimony in this case, you gave it as your opinion that the sewage from the City of Chicago had not produced any effect either
5775 one way or the other, in the waters of the Mississippi river, covering the months of October, November and December, 1901. Please state whether you still entertain that opinion after taking into consideration the tables which you have given in evidence this morning?

A. I don't think there is anything shown by these later examinations to warrant any change in that opinion.

CROSS-EXAMINATION, by Mr. Jeffries:

I have been studying bacteriology practically ever since there was anything known of that science. Before I commenced the study of bacteriology, my line of work was cryptogamic botany. I had studied biology prior to that time.

5781 I think the preponderance of opinion would be that pathogenic bacteria in the open running streams have less advantage than they commonly have in a bacteriological laboratory test.

5786 It is certainly true that the interpretation to be made from the bacteriological examinations must be influenced by the knowledge of the physical conditions and all other mat-

ter pertaining to the sources of pollution. In answer to the question propounded by Mr. Todd, the witness stated:

5792 This bacillus is well known to all bacteriologists, and is made common use of in bacteriological laboratories for various purposes. In my own work, it has been frequently used in connection with other organisms in various kinds of water contaminated and otherwise, and the general result has been that this organism soon dies out in any kind of water.

I happen to have the exact results of an experiment made this last summer, and found that when the bacillus prodigiosus was placed in water entirely sterilized and free from other organisms and kept at about room temperature, though the room temperature at that time varied between 20 and 25 degrees Centigrade, the organism did not last over four days in a living condition. When put in with various other organisms some of which could live continuously in water, it was found that in several instances the bacillus died after a period of three days. In one instance a few of the organisms were found after a period of five days, but in no other case were there any found living up to that length of time.

I think I am entitled to the opinion that under any ordinary circumstance, bacillus prodigiosus will not live in ordinary tap water or in common river water or in sewage polluted water more than five days.

5793 From my bacterial analyses of the water of the Illinois river, I should not consider it proper water to drink. An examination of the data reveals the fact that there were on an average from seven to ten times as many bacteria per cubic centimeter in the water taken from the station at Averyville and also from the mouth of the Illinois river at Grafton as were found in Lake Michigan.

5794 The colon bacilli were found much more frequently, as a common thing, in the water at Averyville and at Grafton, than in the water of Lake Michigan as examined. That organism was very frequently found in the waters of the lake according to my remembrance. I do not think we could call that

water bacteriologically pure. I should not consider it to be very desirable for domestic and drinking purposes according to these tests in many instances.

5795 I will say that a comparison of the tables will generally show that a larg number of colonies of bacteria is accompanied by positive determination of the bacillus coli communis, but there are frequent variations from this, and the particular circumstances cited by you as shown by the tests of the Illinois river at Averyville, seem to belong to this unexplainable variation in the results. I should have anticipated, after finding 102,000 bacteria from the water taken on December 9th, that there would be a positive determination of bacillus coli communis. Our results based upon the particular samples examined, seemed to show that in these samples it was not present. I should by no means take this to mean that it was absolutely absent in the water from that point at that time commcaly. I am not at all surprised to find it present on December 23d, when the number of colonies as made out was 5,900. The greater variation from the ordinary results is in the first instance. But during the fermentive processes continued for some time there is among the organisms present a survival of the fittest and the special water bacteria are likely to be these which ultimately prevail, while bacillus coli communis dies out. This may be one of these instances.

I may say if I may speak generally of this series of investigations at Averyville, for the time from October to December, 1901, that the number of negative results in the tests for bacillus coli communis, is upon the whole, to me quite surprising taken into account with the total number of colonies that were found at that time.

5796 The number of bacteria at Averyville is very considerably greater than that found in the waters of Lake Michigan and the variation is greater. The number found at Jefferson Barracks is very considerably more than the number at the Chain of Rocks, as reported in tables 69 to 72 inclusive, for the Chain of Rocks, and tables 74 to 78 inclusive, for the Jefferson

Barracks. I have not figured out these averages, but as I now glance at the tables, the number is from ten to twenty times the number in the latter instance, that is the number for Jefferson Barracks.

5800 So far as typhoid fever is concerned, I have been led to the belief and understanding that the detection of bacillus coli communis was the best practical test that we had of the possible presence of the organisms causing this disease of typhoid fever. Of course there are other organisms sometimes carried in the water which can be readily identified by proper examination, and when they can be identified, that is the best evidence as to whether this water is proper for potable purposes in respect to those particular diseases.

5801 FREDERICK WILLIAM SCHULE, examined in chief by Mr. Todd:

Am a student at Ann Arbor, Michigan. In the fall of 1901, in October, November and December, I had charge of the laboratory at Peoria and did work under the supervision of Prof. Jordan.

5802 (States where samples were collected and how they were received at the laboratory, etc.)

5803 CROSS-EXAMINATION, by Mr. Jeffries:

(Witness states class of work he was engaged in, etc.)

5804 MR. TODD: I want to offer for the inspection of counsel, all the tags which have been testified to by the water takers at the various points along the river, also the cards which have been offered in evidence as Defendants' Exhibit 3, and the envelope, Defendants' Exhibit 4. I also offer in evidence Sanitary District of Chicago's Exhibit No. 11 for identification, as a sample of all the cards which I have offered for the inspection of counsel and which are in my possession and ask that same be marked Defendants' Exhibit No. 14.

5805 PROF EDWIN OAKES JORDAN, examined in chief by Mr. Todd:

Am instructor at the University of Chicago. Have been connected with the Chicago University since its opening—that

is eleven years I think. I am associate professor of bacteriology.

(Witness states educational qualifications.)

5807 I have made analyses of the water of the Illinois and Michigan canal; of the Chicago drainage canal; of the Illinois river; of the Des Plaines river; of the Kankakee river; Fox river; Big Vermilion river; Sangamon river; Mississippi and Missouri rivers, and of Lake Michigan for the Sanitary District of Chicago.

There are really three periods of time, one extending from April or May, 1899, to the end of the year; the second period extending from the first of January, 1900 to the end of June, 1900, and the third period from October, 1901, to about the first of January, 1902.

5808 (Witness states where samples were taken and the places where taken are indicated on the tables which are to be hereafter introduced in evidence.)

5809 This series as I understand it was taken by agreement with the authorities of the State of Missouri at certain designated points. Those points were at Peoria from a short distance above and below the city; at Grafton at the mouth of the Illinois river, samples being taken from both the Illinois and the Mississippi at this point, and at the Chain of Rocks, the source of the water supply of St. Louis, where samples were taken across the stream as in the preceding examinations. Examinations were also made from the Missouri river at Fort Bellefontaine.

The analyses were made in laboratories which were established under my direction at Peoria, at Grafton and at St. Louis. I think the gentlemen in charge of those laboratories, with the exception of Mr. Irons, have already testified in this case. The laboratory at Peoria was in charge of Mr. F. W. Schule, a

5810 graduate of the University of Wisconsin, who came to me with recommendations as to his ability and experience in bacteriology from Professor H. L. Russell.

The laboratory at Grafton was in charge of Mr. W. S. Sayer,

one of my own graduate students, trained in my laboratory and previously associated with me in other work.

The laboratory at St. Louis was in charge of Mr. E. E. Irons, and Mr. W. G. Sackett.

Mr. Irons also had general supervision of these three laboratories, and although he spent most of his time at the St. Louis laboratory, he visited the laboratories at Peoria and at Grafton at frequent intervals and made reports upon the work to me.

The men in charge of these laboratories sent in written reports of their work to me at weekly intervals and a duplicate copy of this report was also kept on file in the separate laboratories, and was turned in to me at the expiration of the work.

At a conference between Professor Palmer, Dr. Gehrmann, Dr. Reynolds, Mr. Randolph, Dr. Reiley, and myself, in the office of the Health Commissioner of Chicago, the field was gone over in some detail and certain points indicated as being favorable points for collection, in the opinion of the gentlemen attending this conference. In consequence of this conference, Professor Palmer and I were appointed to visit the places indicated, and to determine whether in our opinion these were the most suitable points for the collection of water samples and whether if, that being so, it was possible to make satisfactory arrangements with reliable persons for the collection of such samples at stated intervals.

5811 In March, 1899, we visited most of the points that I have mentioned as being the places from which samples of water were actually collected. In each case we made a special effort to obtain the services of some person whom we supposed to be trustworthy, for the purposes of collecting water samples. These persons were provisionally engaged by us through a personal interview for this purpose.

5813 These samples of water were examined physically, chemically and bacterially.

5814 In the routine work for the bacterial analyses, the number of bacteria capable of forming colonies upon a nutrient agar plate, was the principal determination. Examina-

tions were also made to determine the relative abundance of colon bacillus. (Witness describes the methods employed in collecting, sending, and making bacterial analyses of samples for the years 1899 and 1900.)

5815 In the chemical analyses of these waters the analyses were made for residue on evaporation, chlorine, oxygen consumed, nitrogen as free ammonia, as albuminoid ammonia, nitrogen as nitrites and nitrates. (Witness states methods employed in determining the above constituents.)

5816 As to the physical character of the water, the turbidity and sediment were roughly determined in the laboratory by simple ocular inspection. The color of the water was determined by comparison with Nessler standards. The odor of the water was usually tested, but no attempt was made to classify the odors minutely.

5817 The tables on which the results of the examinations made by this witness have been indicated will be known as Jordan's Tables No. 81 to 158 inclusive.

5818 Table No. 1 reproduced in evidence.

5819 That shows the results of analytical determinations upon the water of the Illinois and Michigan canal at Bridgeport, collected in the manner stated on the days specified in the left hand column. During this period the water from the Chicago river was pumped into the Illinois and Michigan canal. The large amount of chlorine, the large amount of free ammonia and albuminoid ammonia in this water, together with the amount of oxygen consumed by dissolved and suspended matter, and the immense numbers of bacteria show that the water of the Illinois and Michigan canal was on these days simply sewage of varying degrees of concentration and staleness.

5821 Table 82 reproduced on page 5820 embodies analyses made from the water obtained from the Illinois and Michigan canal at Lockport, a distance of some 29 miles from Bridgeport during the period covered from May 5th to December 26th, 1899. The contents of the canal are but slightly diluted during this journey. The significant constituents of the water, the

chlorine, ammonia and the number of bacteria show that but little change has taken place in the constitution of this sewage during this flow, except that it is further advanced in decomposition.

5823 Table 83, reproduced on page 5822, contains the detailed analyses of samples of water from the Des Plaines river at Lockport, Illinois, obtained on different days from May 5th to December 26, 1899. The amount of the several significant constituents of this water indicates a water more or less polluted. The Des Plaines river in fact receives sewage from several of the suburbs of Chicago. The point from which samples were taken was above the mouth of the present drainage canal. From the analyses of this water, as well as from the known facts regarding the entrance of sewage into the Des Plaines river, I should not regard this water as being potable at this point. At the time these analyses were made in table 83, the Des Plaines river received sewage only from the suburbs of Chicago, Riverside and other places that directly empty into it. The Des Plaines river at this point had not received any of the sewage of Chicago, entering the Chicago river.

5825 The samples of water the analyses of which appear in table 84, reproduced on page 5824, were obtained from the Des Plaines river north of Jackson street at Joliet, Illinois on the various dates between May 4th and December 26th, 1899. The Des Plaines river between the point on the Des Plaines river at which the samples appearing in table 83 were taken and Joliet, received the contents of the Illinois and Michigan canal. From the chemical and bacterial constituents of this water, it is evident that the mingling of the waters of the Des Plaines with the waters of the Illinois and Michigan canal have resulted in little alteration of the composition of the canal water. In other words, the canal water was but slightly diluted. The Des

Plaines river at this point must be regarded as a stream charged with sewage.

5827 Table 85 is reproduced on page 5826 and embodies the analyses of samples of water taken from the Des Plaines river just below the town of Joliet. The analyses were made on the various dates between May 4th, 1899, and September 18th, 1899. At this latter date the analyses were terminated owing to the interference of construction work with the taking of samples at this point. The sewage of Joliet enters the stream in this vicinity.

5828 Table 86 shows result of examination of the Chicago river at Wilmington, Illinois.

5829 Table 87, reproduced on page 5830, contains analyses of samples of water taken from the Illinois river at Morris, Illinois, between May 29th and December 26th, 1899. About nine miles above Morris the waters of the Kankakee mingle with the waters of the Des Plaines river, forming by their junction the Illinois river proper. The water of the Illinois river at Morris therefore shows the influence of dilution of the highly polluted Des Plaines river with the purer waters of the Kankakee, although the commingling is not complete at this point.

Some change in the composition of the water appears also to have taken place during its passage from Bridgeport to Morris.

Q. What is the nature of that?

A. A diminished amount of albuminoid ammonia and increased amount of free ammonia. The number of bacteria is however, still high.

5833 Table No. 88, reproduced on page 5832, includes the analyses of water from the Fox river near its mouth at Ottawa, Illinois, the samples being taken from between May 29th and December 28th, inclusive, 1899.

Sewage from several towns enters the Fox river, the principal towns being Elgin, with a population of about 22,000, and Aurora with a population of about 26,000. Aurora is about 40 miles about the mouth of the Fox, and Elgin about 55 miles.

The composition of the water is what might be expected from its origin.

It is a river water receiving some sewage.

5835 Table No. 89, reproduced on page 5834, contains the results of analyses of water from the Illinois river at Ottawa, Illinois, samples being taken from June 19th, to Decemreb 28th, 1899. In the flow from Morris to Ottawa a very considerable change takes place in the composition of the water. This is partly due to more thorough mixing, but in a large part due to changes in the constituents of the water. The albuminoid ammonia and free ammonia, the oxygen consumed the number of bacteria are all lower than at Morris, indicating that a really considerable purification of the water has taken place during its passage from Morris to Ottawa.

5837 Table 90, reproduced on page 5836, includes the analyses of water from a tributary of the Illinois river, the Big Vermilion river, entering the Illinois above La Salle. Samples of water being taken a short distance above the mouth of the Big Vermilion, between May 24th, and December 26th, 1899. The sewage of Streator and Pontiac enter the Big Vermilion. The determinations for chlorine and residue on evaporation were influenced by the operations of a cement factory a short distance above the point of collection. This affords an explanation for the large amount of residue on evaporation and for the high chlorine in September, October and November of this year.

5839 Table No. 91, reproduced on page 5838, contains the analyses of samples of water from the Illinois and Michigan canal at La Salle. The samples were taken between May 24th, and December 26th, 1899. The samples were taken just before the canal discharges into the Illinois river. Some of the sewage from La Salle enters the canal.

The large amount of free ammonia and albuminoid am-

monia and the large number of bacteria show considerable pollution is present at this point.

5841 Table 92, reproduced on page 5839 contains the analyses of samples from the Illinois river at La Salle. The samples were taken above the town and were taken between May 24th, and December 26th, 1899.

The various determinations show that considerable purification has taken place in the Illinois river during the flow from Ottawa to this point, a distance of 22 miles.

5843 Table 93, reproduced on page 5842, contains the analyses of water from the Illinois river at Henry, Illinois. The samples were taken between May 30th and December 27th, 1899. The samples at Henry were taken above the dam. At La Salle the sewage and drainage of La Salle and Peru, with a combined population of about 17,000 enters the Illinois and Michigan canal, which discharges into the river, and into the river itself. Little additional impurity enters the river between La Salle and Henry, and little dilution enters.

5845 Table 94, reproduced on page 5844, contains the analyses of samples of water from the Illinois river at Averyville, Illinois, the samples being taken on various dates between May 30th and December 26th, 1899.

Between Henry and Averyville there is practically no addition of impurity and little dilution, so that the changes occurring in this flow of 36 miles are due to oxidation and other processes. The point where the samples were taken is at the place known as the Narrows, near the Peoria waterworks above the city of Peoria, and before any pollution from the city enters the river.

The large amount of nitrogen in the form of nitrates at this point shows that a very considerable amount of oxidation of the organic matter has taken place. The small number of bacteria shows that the stream which was originally laden with the bacteria of the Chicago sewage derived from the Illinois and

Michigan canal has practically freed itself from these bacteria in this flow of about 160 miles.

5847 Table 95, reproduced on page 5846, contains analyses of samples of water taken from the Illinois river a short distance below Peoria near the place know as Wesley City. The samples of water were taken on different dates from May 29th, to December 28th, 1899. A large part of the sewage of Peoria, a city with a population of about 60,000, enters the Illinois river between Averyville and Wesley City. In addition to the house sewage the discharges from extensive stock yards, the slop from distilleries and other refuse enter the river above this point of collection. The large number of bacteria in the water indicates the organic character of a large part of this pollution and shows the extent as well as the nature of the defilement.

5849 Table 96, reproduced on page 5848, contains analyses of samples of water taken from the Illinois river at Pekin between May 24th, and December 28th, 1899. The mixing of the Peoria sewage and refuse with the river water has become more nearly complete by the time this point is reached, and in addition to the sewage of Pekin, a city with a population I believe of about 8,000, has entered the river, together with considerable distillery refuse. The sample was taken far enough below Pekin to get the effect of all this pollution, and so far as practicable to show the mixing of the pollution, although here, as at Wesley City, the amount of pollution shown by the water in the middle of the stream was not the same at all times.

5851 Table 97, reproduced on page 5850, contains analyses of samples of water from the Illinois river at Havana, Illinois, the samples being taken between May 30th, and December 20th, 1899. A considerable degree of purification takes place between Pekin and Havana, as shown by the different determinations in this table.

5853 Table 98, reproduced on page 5852, contains analyses of samples of water taken from the Sangamon river at Chandlerville, Illinois, between May 31st, and December 20th, 1899. The samples from this river were taken from Chandler-

ville because it is the last easily accessible point above the mouth of the Sangamon. Chandlerville is about 20 miles above the mouth. A very considerable amount of sewage enters the Sangamon river and its tributaries, from Springfield, with a population of about 35,000; from Bloomington, with a population of about 24,000; and from Decatur with a population of about 20,000. This very considerable amount of pollution is not particularly manifest in any of the determinations in this particular table, but it comes out with considerable clearness in the determinations that were made for the relative abundance of the colon bacillus, as will be shown in tables that will be presented later.

5855 Table 99, reproduced on page 5854, contains analyses of water from the Illinois river at Beardstown, Illinois, taken between May 24th, and December 28th, 1899. Between Havana and Beardstown the Sangamon river enters, but otherwise little additional impurity is added to the river.

5857 Table 100 contains analyses of samples of water taken from the Illinois river at Kampsville, Illinois, between May 31st and December 20th, 1899. Between Beardstown and Kampsville only a very small amount of polluting material enters the Illinois river. In fact, from Beardstown to the mouth of the river at Grafton, the polluting matters entering the river are relatively insignificant. Some dilution, however, occurs from small tributary streams. The small number of bacteria found on many occasions in the water of the Illinois river at Kampsville, together with the amount of nitrates in the water, shows that the river at this point has practically regained the condition that it possessed at Averyville, above Peoria.

5859 Table 101, reproduced on page 5858, contains the analyses of samples of water taken from the Illinois river at its mouth at Grafton, the samples being taken between May 10th and December 27th, 1899. These samples were taken at a point in the Illinois river where no mixing with Mississippi river water was possible. The condition of the Illinois river at this point compares very favorably chemically and bacterially with

the water of the Illinois river at Averyville and with the tributary streams entering the Illinois.

5861 Table 102, reproduced on page 5860, contains the analyses of samples of water taken from the Mississippi river at Grafton, Illinois, the samples being taken between May 10th and December 27th, 1899. The collections were made at a point in the Mississippi river where no mixing of water with the Illinois river was possible.

From a sanitary standpoint, the water of the Mississippi river above Grafton, does not differ materially so far as can be determined by chemical and bacterial examinations, from the water of the Illinois river at its mouth.

5867 Tables 103, 104, 105, 106 and 107 are reproduced on pages 5862 to 5866 inclusive, and contain results of analyses of samples of water taken from the Mississippi river above Alton, about twenty miles below the mouth of the Illinois river. The samples were taken at approximately equi-distant points across the river, with a view to determining so far as practicable, the extent of mingling of the waters of the Illinois and the Mississippi rivers at this point.

Table 103 contains the analyses of samples taken 100 feet from the Illinois shore.

Table No. 104 contains the analyses of samples taken one-fourth of the distance from the Illinois shore to the Missouri shore.

Table 105 contains the analyses of samples taken from mid-stream.

Table 106 contains the analyses of samples taken one-third of the way from mid-stream to the Missouri shore.

Table 107 contains the analyses of samples taken from the Mississippi river 100 feet from the Missouri shore.

The degree of the commingling of the waters of the Illinois and Mississippi at this point is approximately shown by the chlorine determinations. The higher chlorine on the east bank shows that a portion of the Illinois river water still hugs the

Illinois shore, and that the water west of mid-stream to the right bank was largely if not altogether Mississippi river water.

5869 Table 112, reproduced on page 5868, contains the analyses of samples of water taken from the Missouri river at Fort Bellefontaine, West Alton, Missouri, between July 27th and December 28th, 1899.

Owing to difficulties in making arrangements for collection of samples, the analyses of water from this source were begun later than in the other cases, so that the average of these determinations is not strictly comparable with averages of other determinations covering a different period.

5874 Tables 108, 109, 110 and 111 are reproduced on pages 5870 to 5873 inclusive. These tables contain analyses of samples of water taken in cross-section from the Mississippi river at the Chain of Rocks opposite the pumping station of the St. Louis waterworks.

Table 108 contains the analyses of samples taken about 400 feet from the Illinois shore.

Table 109 containing the analyses of samples taken in mid-stream.

Table 110 contains the analyses of samples taken at the inlet tower of the St. Louis waterworks.

Table 111 containing the analyses of samples taken from the Mississippi river 400 feet from the Missouri shore.

Between Alton and the Chain of Rocks, the Missouri river enters the Mississippi river some six miles above the point of collection.

The Missouri river like the Illinois river, has a high chlorine content, and contains as a rule, more bacteria per cubic centimeter than the waters of either the Mississippi or the Illinois.

5880 Tables 113, 114, 115, 116 and 117, contain analyses of a series of samples taken from the Mississippi river at Jefferson Barracks, Missouri, about nine miles south of Eads bridge.

Table 113 containing the analyses of samples from the east bank, 100 yards from the Illinois shore.

Table 114 containing the analyses of samples taken between this point and mid-stream.

Table 115 the analyses of samples taken from mid-stream.

Table 116 containing the analyses of samples taken from a point one-third of the way from mid-stream, to the Missouri shore.

Table 117 containing analyses of samples taken about 100 yards from the Missouri shore.

I might state that the sewage of St. Louis enters the Mississippi river above Jefferson Barracks.

These tables are reproduced on pages 5875 to 5879, inclusive.

5882 Table 118, reproduced on page 5881, contains the analyses of samples of water drawn from the tap in the city of St. Louis, Missouri. The diminished amount of suspended matter and the smaller number of bacteria in the tap water bear witness to some of the changes effected in the passage of the Mississippi river water through the settling basins. These tables that have been read in evidence, numbered 81 to 188, inclusive, are for periods prior to the opening of the canal. The printed tables numbered from 119 to 158 inclusive, cover the period from the 1st of January to June, 1900, after the canal was opened.

5884 Table 119, reproduced on page 5883, contains the analyses of water taken from the Chicago drainage canal at Kedzie avenue, nine samples of water being taken between April 30th, and June 25th, 1900. As compared with the character of the water in the Chicago river pumped into the Illinois and Michigan canal at Bridgeport during the period covered by the analytical work of 1899, these analyses indicate a water pro-

portionately much less impure and much less heavily loaded with organic matter.

5886 Table 120, reproduced on page 5885, contains analyses of samples of water taken from the Illinois and Michigan canal at Bridgeport, from January 2d, to April 23d, 1900. Some effect of the dilution of the contents of the Chicago river is shown by the various determinations being during this period less highly charged with putrescible organic matter than was the case before the opening of the drainage canal with the consequent influx of purer water from Lake Michigan. At the same time the proximity of the pumping station at Bridgeport to the south Branch of the Chicago river, which is a practically dead end, allowed at times much organic matter and many bacteria to enter the canal.

5888 Table 121 contains the analyses of water taken from the Illinois and Michigan canal at Lockport from January 2d to June 25th, 1900.

The change in flowing from Bridgeport to Lockport during this period is as in the 1899 series, not a marked one.

5890 Table 122 reproduced on page 5889 contains analyses of samples of water taken from the Des Plaines river at Lockport between January 2d and June 25th, 1900. During this period more water was flowing down the Des Plaines valley than in the 1899 period, and this led to a change in the composition of the water that is shown among other things by the increased number of bacteria.

5892 Table 123, reproduced on page 5891, contains analyses of samples of water taken from the Chicago drainage canal at the Bear Trap Dam at Lockport, between April 16th and June 25th, 1900.

5894 Table 124, reproduced on page 5893, contains analyses of samples of water taken from the Des Plaines river north of Jackson street at Joliet, between January 2nd, and June 25th, 1900. Owing to the work in progress on the levees in the neighborhood of Joliet during the latter part of 1899 and 1900, the samples from this station were not always taken at exactly

the same point, and some of the divergencies shown by the analytical data can properly be attributed to this fa-

5896 Table 125, reproduced on page 5895, contains analyses of samples of water taken from the Des Plaines river at Jefferson street, Joliet, between March 5th and June 25th, 1900. The statements made in regard to the collection of samples at Jackson street, Joliet, (table 124) apply here also.

5898 Table 126, reproduced on page 5897, contains analyses of samples of water taken from the Kankakee river at Wilmington from January 2nd to June 23rd, 1900.

I should like to make a correction in the column of figures under "Height of water." The first two figures in the column refer to feet. The following figures to height of water in inches, which by an oversight were not reduced to feet as they should have been to be strictly comparable with the 1899 table. One of the chief differences between the analyses of the Kankakee river for 1899 and 1900, appears in the number of bacteria per cubic centimeter, the number being higher through the winter and early spring months of 1899.

5900 Table 127, reproduced on page 5899, contains the analyses of samples of water taken from the Illinois river at Morris between January 5th and June 26th, 1900. During the month of January the conditions were not dissimilar to those prevailing during 1899, but the analyses for subsequent days show in several ways the effect of the dilution of the Chicago sewage in the Chicago drainage canal.

The smaller amount of chlorine particularly is evidence of this increased dilution and on several occasions notably in the month of May, the number of bacteria in the Illinois river at this point was lower to a striking degree, than at any time in the preceding period.

Q. How is the great number of bacteria in the month of January and the small number of bacteria in comparison in the months of April, May and June, explained in this table 127?

A. The difference may be in part at least explained by the fact that during the early part of January, 1900, the water from

the drainage canal was not flowing into the Des Plaines river, but the water from the Illinois and Michigan canal was entering the Des Plaines river during that period.

5902 Table 128, reproduced on page 5901, contains analyses of samples of water from the Fox river at Ottawa between January 4th and June 25th, 1900.

During the early part of this period the number of bacteria was much higher than in the period of 1899 and much higher than for the latter part of April and for May and June, 1900. This is a phenomenon of common occurrence in river waters and so far as I am aware no adequate explanation of this occurrence has been adduced.

5904 Table 129, reproduced on page 5903, contains analyses of samples of water from the Illinois river at Ottawa between January 4th and June 25th, 1900. The various determinations chemical and bacterial, especially those showing the amount of albuminoid ammonia, free ammonia and nitrates and the number of bacteria per cubic centimeter, indicate that a considerable change in the direction of purification has taken place between Morris and Ottawa as in 1899.

5906 Table 130, reproduced on page 5905, contains analyses of samples of water from the Big Vermilion at La Salle, the samples being taken between January 2nd and June 26th, 1900. The number of bacteria during this period is on the whole higher than in the period for 1899. The amount of free ammonia during the first part of this period is much higher than in the latter part of the period.

5908 Table 131, reproduced on page 5907, contains analyses of samples of water from the Illinois river at La Salle between January 2nd and June 26th, 1900. During the months of January, February and March, the number of bacteria in the river is, as in the other river waters that have been considered, much higher than during 1899. The amount of free ammonia is

likewise much higher during the first part of this period than during the latter portion.

5910 Table 132, reproduced on page 5909, contains analyses of samples of water from the Illinois and Michigan canal at La Salle from January 2nd to June 26th, 1900. I should like to strike out in table 131 the height of water in the Illinois river at La Salle for February 6th, as being obviously a clerical error.

5912 Table 133, reproduced on page 5911, contains analyses of samples of water from the Illinois river at Henry between January 3rd and June 25th, 1900. Here again is shown the increase in the number of bacteria in the river water during the late winter and early spring. This has already been shown to be a common phenomenon in river water and occurs in the tributaries of the Illinois as well as in the Illinois itself. The diminished chlorine in the latter part of this period shows the effect of the dilution due to the opening of the Chicago drainage canal.

5914 Table 134, reproduced on page 5913, contains analyses of samples of water in the Illinois river at Averyville from January 2nd to June 26th, 1900. Both the effects of purification and dilution are shown in this table, especially during the latter part of the period when the effect of the condition of early spring had disappeared.

5916 Table 135, reproduced on page 5915, contains analyses of samples of water in the Illinois river at Wesley City. The smaller number of bacteria during this period as compared with the 1899 period shows that the pollution entering the Illinois river at Peoria, has been crowded in part towards the western bank and does not make its presence so evident in mid-stream as was the case during 1899.

5918 Table 136, reproduced on page 5917, contains analyses of samples of water taken from the Illinois river at Pekin from January 11th, 1900, to June 27th, 1900.

The effect of pollution here in mid-stream sample is more manifest than in the samples from Wesley City owing possibly to a more thorough mixing at this point.

5920 Table 137, reproduced on page 5919, contains analyses of samples of water taken from the Illinois river at Havana, between January 11th and June 27th, 1900. The purification in the river as shown by the amount of nitrates and the number of bacteria is manifest here as well as in the 1899 period.

5922 Table 138, reproduced on page 5921, contains the analyses of samples of water from the Sangamon river at Chandlerville, from January 3rd and June 27, 1900. The usual spring increase in the number of bacteria is manifest at this point as in the other tributaries of the Illinois and in the Illinois river itself.

5924 Table 139, reproduced on page 5923, contains analyses of samples of water from the Illinois river at Beardstown from January 4th to June 28th, 1900. Taking into consideration the greater dilution of the water at this point, the analytical data are not materially different from those covering the 1899 period.

5926 Table 140, reproduced on page 5925, contains analyses of samples of water taken from the Illinois river at Kampsville from January 3rd to June 27th, 1900. The usual spring rise in the number of bacteria, the amount of free ammonia and albuminoid ammonia and so on, is manifest here as elsewhere, but during the latter part of the period the condition of the water both chemically and bacterially compares very favorably with that in the 1899 period.

The number of bacteria averages less at Kampsville than at Averyville. The amount of free ammonia is on the whole lower. The albuminoid is very similar.

The nitrates are on the whole lower at Kampsville than at Averyville during this period.

The nitrates are also lower, and the oxygen consumed on the whole does not differ materially.

5928 Table 141 reproduced on page 5927 contains analyses of samples of water from the Illinois river at Grafton, taken between January 4th, and June 29th, 1900.

A very considerable degree of purification is shown chemically, and in the latter part of the period bacterially also, as compared with the collecting stations in the upper stretches of the river. The increased volume of water in the Illinois river, especially in the months of March and April, is reflected in the lower chlorine content during this period.

5930 Table 142 reproduced on page 5929 contains analyses of samples of water taken from the Mississippi river at Grafton, Illinois, the samples being collected between January 4th and June 29th, 1900.

The amount of albuminoid ammonia in the water of the Mississippi during this period is on the whole somewhat higher than the amount in the Illinois river in samples taken on similar dates.

5936 Tables 143 to 147 reproduced on pages 5931 to 5935, inclusive, show the analyses of a series of five samples taken approximately equi-distant points, across the Mississippi above Alton, Illinois.

The points of collection were the same as during the 1899 period.

The analyses show that in the 1899 period, there is a lack of complete commingling of the waters of the Illinois and Mississippi river at this point, the water derived from the Illinois river clinging as before, to the left bank of the Illinois shore, as is shown particularly by the chlorine and nitrate determinations.

5938 Table 152 reproduced on page 5937 contains the analyses of samples of water taken from the Missouri river at Fort Bellefontaine, West Alton, Missouri, between January 4th and June 27th, 1900.

The large amount of suspended matter carried by the Missouri river in high water periods is shown by these determinations, especially by the suspended residue on evaporation, by

the amount of oxygen consumed by suspended matter, and by the amount of nitrogen present in the form of albuminoid ammonia in suspended matter. Throughout the greater part of this period also the number of bacteria in the Missouri river water was high.

5943 Tables 148, 149, 150 and 151 reproduced on pages 5939 to 5942, inclusive, contain analyses of samples of water taken from the Mississippi river opposite the pumping station of the St. Louis waterworks at the Chain of Rocks between January 5th and June 28th, 1900, the samples being collected from the same points as were specifically designated for the 1899 period.

The considerable amount of suspended matter, as is shown by the residue on evaporation, which was present in the water of the Mississippi river at the inlet tower and in midstream at this point, when compared with the smaller amount of suspended matter in the Mississippi river above the entrance of the Missouri, indicates that the major part of the water entering the St. Louis water intake during the period covered by these analyses was derived from the Missouri river than from the Illinois.

5949 Tables 153, 154, 155, 156 and 157 reproduced on pages 5944 to 5948, inclusive, include samples of water taken from the Mississippi river at Jefferson Barracks, Missouri, below the city of St. Louis, between January 4th and April 26th, 1900, the points at which the samples were collected being the same as those specified more particularly for the 1899 period. Aside from the changes attributable to the differences already noted in the composition of the Illinois, Mississippi and Missouri river waters, the analyses at this point contained nothing of special significance.

5951 Table 158, reproduced on page 5850, contains analyses of samples of water drawn from the tap at St. Louis, Missouri, the samples being collected between January 4th and June 28th, 1900. The large amount of suspended mater in the water of the Missouri river during the latter part of this period is reflected in the increased residue on evaporation in suspended matter in the tap water, although the reduction in pasage

through settling basins is very great. (Motion by Mr. Jeffries to strike out tables No. 81 to 158.) The physical characters of the water have been roughly determined with reference to the amount of turbidity, amount of sediment, the color and odor. Little or no sanitary importance can be attached to the turbidity, sediment and color in the cases under consideration. As regards the odor of the water, it is found that, in general,

waters containing a large amount of organic matter in
5952 the early stages of decomposition, possess an offensive odor readily perceived by the senses, while less impure water or waters further advanced in the procession of oxidation possess little odor, or, it may be, none at all. It sometimes happens, however, that waters containing a large number of microscopic forms of life, chiefly algae and infusoria, yield odors that are more or less offensive, and that simulate the odors of decomposition. The death and disintegration of these microscopic forms may likewise be the cause of disagreeable smells. Offensive odors, then, may or may not be accompanied by dangerous sanitary qualities.

Turning next to the various chemical determinations, we may first consider the residue on evaporation. This determination gives information as to the amount of solid substance remaining after the water in which it was dissolved or suspended has been completely evaporated. During the process of thorough drying, certain substances, organic and mineral, are decomposed and driven off.

In general polluted waters contain a rather high residue on evaporation, but in certain cases the residue on evaporation may have reference simply to harmless mineral matters in suspension. In all cases a distinction was made between the dissolved residue on evaporation and the suspended residue on evaporation, the determinations being made both upon filtered and unfiltered samples, the difference between the two being taken as the weight of the residue in suspension.

The determinations of chlorine may next be considered. Chlorine is present in practically all natural waters in combination with sodium in the form of sodium chloride or common salt. Owing to the large amount of salt in urine and in various forms of household waste, it has been found that sewage contains an amount of chlorine in marked excess of that present in most natural and unpolluted ground and surface waters.

When the amount of chlorine normally present in the unpolluted wells and springs of a given district is accurately known, it becomes possible to determine with a considerable degree of precision the amount of pollution existing in the various ground and surface waters of that region which have received a larger or smaller amount of drainage.

The content of a water in sodium chloride is therefore under some conditions a fairly satisfactory gauge of the
5953 sanitary condition of that water. Owing to the permanence of the salt, however, the amount of chlorine in a polluted water does not afford conclusive indications as to whether the pollution is recent or remote. In following the passage of salt down stream in a polluted river, the permanency of this substance renders it a valuable indication of the degree of dilution and mixing, but on the other hand, does not afford a clue to the rapidity and extent with which processes of oxidation and bacterial purification are taking place.

The determinations known as oxygen consumed concerns especially the carbonaceous matter in the water.

The significance of this determination lies in its comparative rather than its absolute value, since the amount of oxygen consumed as determined by the quantity of permanganate solution consumed during heating, is affected materially by the period of heating, and by other factors. Exact uniformity of the analytical process involved is therefore of great importance, and in order that the results in one and the same laboratory shall be strictly comparable throughout it is necessary to maintain perfect uniformity of procedure. The changes necessary to maintain perfect uniformity of procedure. The changes taking place

in carbonaceous matter in a water cannot be followed step by step as is the case with nitrogenous compounds, since the carbon di-oxide formed in decomposition processes either goes off, or enters into combination with mineral elements.

The most significant organic compounds in a polluted water are those of nitrogenous character. These nitrogenous compounds are usually determined in four different states, as albuminoid ammonia or organic nitrogen, as free ammonia, as nitrites and as nitrates.

If we follow the history briefly of the waste nitrogenous compounds discharged from the animal body it is as follows:

These compounds are at first relatively complex and are chemically highly organized bodies. When subjected to bacterial action free ammonia is liberated from these substances, and enters into loose combination with certain of the elements present in the water or sewage. When a water into which such matters have been received a short time before is heated, the ammonia is driven off in the steam and can be collected and measured with a considerable degree of accuracy.

This is the so-called free ammonia in the analytical tables.

The nitrogen in the more chemically complex substances
5954 on the other hand, is for the most part not driven off by this process. This is the so-called albuminoid ammonia, the amount of which, however, can be determined by heating in an alkaline solution in the presence of permanganate, destruction of the albumen or nitrogenous molecule taking place under these conditions. This process results in the liberation of ammonical compounds which can then be distilled over, collected and measured by the same method as used for the determination of the free ammonia.

In general it may be said that a fresh sewage contains a relatively large proportion of nitrogen in the form of albuminoid ammonia, while a stale sewage contains a smaller proportion of nitrogen in the form of albuminoid ammonia, bacterial activity having converted the albuminoid ammonia into free ammonia.

These early stages in the decomposition of organic matter are followed by oxidation processes which result in the conversion of the free ammonia of the water into nitrites, nitrites being less highly energized compounds than the ammonical compounds from which they have been derived. The reason for this oxidation process resides in the need of bacteria for food. Food being matter containing available potential energy, many kinds of bacteria are able to obtain this energy from the ammonium compounds.

Under favorable conditions the process of oxidation does not stop here, as certain bacteria are able to obtain the energy necessary for their development even from compounds containing so little available potential energy as nitrites, and are able to carry on their vital processes with the aid of the energy derived from the oxidation of the nitrites, which by virtue of this bacterial activity are converted into mineral nitrates, the nitrogen then passing successively through the various stages of albuminoid ammonia, free ammonia, nitrites and nitrates. The oxidation of the free ammonia into nitrites and of the nitrites into nitrates is what is termed the process of nitrification. The importance of these facts from the sanitary side is due to the connection of these oxidation processes with processes of purification.

5953 In general, large amounts of albuminoid and free ammonia indicate the existence of products of decomposition, while the presence of a large amount of nitrate, together with little free and albuminoid ammonia and little nitrite, characterizes a water which may perhaps in the past have received a considerable quantity of polluting matter, but which after the lapse of time, and through bacterial activity has become relatively stable. It has been found empirically that waters in which these oxidation processes have taken place, less commonly give rise to disease, or are a source of danger, than waters that have received recent pollution, as indicated by the relatively high amounts of free and albuminoid ammonia.

The number of bacteria in a water is usually determined by mixing an accurately measured quantity of the water with nutrient beef jelly and then pouring the mixture out into a sterilized glass dish. The theory underlying this procedure is that each germ originally present in the water, finding itself in a favorable nutrient medium, grows, multiplies and in a few hours or days has formed about itself a growth or colony large enough to be plainly visible to the naked eye.

Different kinds of bacteria form colonies that can be distinguished, one from the other, by various physical characters. The kinds of bacteria in a water vary greatly in their sanitary significance, most being perfectly harmless saphrophytic forms, which do not so far as is known, have any injurious effect upon the human system, even when taken into the alimentary tract in large quantities. Others, the poisonous or so-called pathogenic germs, are able when taken into the animal body, under suitable conditions, to produce poisonous substances which damage the organism.

The number of bacteria per cubic centimeter as enumerated in the analytical tables 81 to 158 includes the colonies of all kinds developing upon the bacterial plates, no distinction being made between the harmless and injurious kinds.

By enumerating the number of colonies occurring on one of these plates of beef jelly or nutrient gelatin, some approximation can be arrived at regarding the number of germs originally present in the water, although the absolute number of bacteria in water is not always convincing evidence of the sanitary
5956 quality of water, since under certain laboratory conditions, bacteria may be made to multiply in a pure water. At the same time experience has shown that in waters collected under natural conditions from springs, rivers, lakes and reservoirs, the purer waters contain fewer bacteria, while those waters that are polluted with sewage or large quantities of organic matter, contain numbers of bacteria much in excess of those found in purer waters. Under natural conditions, it is in general true, that as the food supply of bacteria diminishes, the

number of germs becomes fewer, while an influx of food material favors the longevity of certain bacteria and their further multiplication. Surface waters contain as a rule, larger numbers of bacteria than ground waters, which have been freed of a portion of their bacterial content by filtration through layers of sand or soil. It has been observed that the water of a sewage polluted river may contain large numbers of bacteria just below the source of the pollution, but that these numbers diminish with the passage of the water down stream.

I have made a table of comparative averages of the different chemical and bacterial analyses from tables No. 81 to 158 both inclusive for the years 1899 and 1900.

5957 This table of averages is designated as Table E and Table E continued, and is contained on two sheets and reproduced on pages 5958 and 5959.

5960 From an examination and consideration of the tables of separate analyses and the tables of averages for this period, the period of 1899, it appears that the water in the Illinois and Michigan canal at Bridgeport and Lockport, as well as the water of the Des Plaines river at Joliet and of the Illinois river at Morris, contained throughout this period a large amount of nitrogenous organic matter in the early stages of decomposition. It appears also from the large amount of chlorine present in these waters that the initial pollution of the Illinois river reached a considerable height during this period. The large number of bacteria present in these waters shows that the substances capable of serving as food for these organisms were present in great abundance.

5961 The tables and averages also show that by the time the Illinois river reaches Ottawa, being somewhat diluted in its course by the purer waters of the Kankakee, mingling with which is incomplete at Morris, a very great change has taken place in the composition of the river water, a change which is manifested especially by the diminution in the amount of albuminoid ammonia by the increase in the amount of nitrites and

nitrates, and particularly by an enormous and significant diminution in the bacterial content.

The oxidation of the organic matter continues with the passage of the water down stream and by the time the flow reaches Averyville the amount of free ammonia is greatly diminished as compared with the amount at Ottawa. The amount of albuminoid ammonia is diminished. The amount of nitrates has greatly increased, while the bacteria which were present in such enormous numbers in the waters of the upper Illinois have now sunk to a point where they can be compared with the number present in ordinary surface waters in the United States and with the number present in the tributaries of the Illinois during this period.

Below Averyville the Illinois river receives a large influx of polluting material from Peoria with its stock yards and distilleries, which is evidenced by the increase in some of the significant constituents in the river water, notably in the free ammonia and the albuminoid ammonia and in the number of bacteria.

At Pekin some additional sewage is received and the mingling of the Peoria sewage with the Illinois river water has become more perfect. From Pekin to the mouth of the river, the purification follows a generally progressive course, until by the time the mouth of the river is reached at Grafton, the amount of free and albuminoid ammonia, the oxygen consumed by the carbonaceous matter and the number of bacteria are again low, while the relatively large amount of nitrates bears witness to the practically complete oxidation of the enormous amount of organic matter with which the sewage was laden at Peoria, as well as that with which it originally set forth at Lockport.

5963 The conditions in the Illinois river during the larger part of the period covered by these investigations are shown by analyses of samples collected at the same points and under the same conditions as in 1899, the whole series of analyses from May, 1899, to the end of June, 1900, forming one continuous period.

From April to June, 1900, analyses were made of the water from the Chicago drainage canal at Kedzie street and at Lockport. These analyses show that as compared with the condition of the water in the Chicago river considerable dilution has taken place as witnessed particularly by the chlorine determination, as well as by similar changes in the other constituents of the sewage.

A mingiling of the waters coming from the Chicago drainage canal at Lockport and from the Illinois and Michigan canal at Lockport, with the waters of the Des Ploines river which is subsequently joined by the Kankakee, took place during this period. The first admixture of the waters of the drainage canal took place on the 17th of January, 1900, after the canal had been filled and the gates finally opened.

Examination of the separate analyses of the samples of water from the Illinois river at Morris and also of the averages of these analyses, shows that the water of the river at this point was charged with organic matter; that it contained a large amount of nitrogen in the form of albuminoid and of free ammonia; that the amount of oxygen consumed was high, and that the number of bacteria was still large.

5964 The samples of water taken from the Illinois river at Ottawa during this same period showed that considerable purification took place between Morris and Ottawa, the amount of free ammonia and of albuminoid ammonia and of oxygen consumed, being diminished, and the number of bacteria being little more than one-fourth the number in the Illinois river at Morris during this period.

By the time Averyville is reached the process of purification had proceeded still farther, both free and albuminoid ammonia being notably lower than at Ottawa.

At this station also the amount of nitrate was high, showing that considerable nitrification had taken place in the flow from the drainage canal to this point. The number of bacteria was not half as great as in the Illinois river at Ottawa during the same period.

A further addition of polluting water took place at Peoria and Pekin, with the result that in the lower half of the river the process of purification had again to be completed. How complete this purification was may be seen from the determinations at Grafton for this period, the amount of free and albuminoid ammonia in the water and the amount of nitrates indicating that this purification followed a parallel course to the purification in the upper half of the river.

The second period, the conditions in which have been just described, has been arbitrarily separated from the first period, namely, that for the months May to December 1899, but the analyses show plainly that the essential course of events in the water of the Illinois river is the same, whether a period of two months, or five months or fourteen months, be considered.

In all cases the same phenomenon is noticed. The water at the outset, highly charged with putrescible organic matter and laden with sewage material, regains in the course of about 130 miles flow the condition usually existing in surface waters in this country.

5965 Witness gives reasons for the following statement: From
5966 a comparison of the analytical data therefore, at this point, it is evident that the separation of the two periods on the basis of calendar years, is from the point of view of sanitary water analysis, an arbitrary one, and does not bear any definite relation to any meteorological or biological conditions. So far as the chemical and bacterial determinations show, the condition of the Illinois river at Averyville, Kampsville and Grafton differs in but slight and insignificant particulars from the waters of the tributary streams. Witness then makes comparisons between the tributaries of the Illinois and the waters of the Illinois at various points.

5967 The number of bacteria in the Illinois river at Grafton being lower than the number in the Sangamon river at Chandlerville, and almost exactly the same as the number in the Fox river at Ottawa, and the Big Vermilion river at La Salle for this period; so that considered from the point of view of a

comparison of the chemical and bacterial analyses, the condition of the Illinois river at Averyville, Kampsville and Grafton, compares favorably with the important tributaries of the Illinois.

5968 Throughout the period covered by this investigation, namely, from May, 1899 to the end of June, 1900, the water of the Illinois river at Pekin was usually in a more highly polluted condition chemically and bacterially, than the water of the Illinois river at Averyville. The large amount of sewage and refuse that enters the Illinois river at Peoria and at Pekin offers a sufficient explanation in my opinion for the increased pollution of the Illinois river at this point as compared with the condition of the river above Peoria, at Averyville, before this pollution enters. It is a somewhat difficult question to answer as to how far down the river from Peoria the pollution which the Illinois river takes on at Peoria, disappears, because the conditions undoubtedly vary at different times of the year and with different rates of flow. The water of the Illinois river at Havana is on the whole, considered in the light of the chemical and bacterial examinations given in these tables in a less satisfactory condition than the water of the Illinois river at Averyville. The same might possibly be said on some occasions, of the water of the Illinois river at Beardstown; at Kampsville and at Grafton. However, the water of the Illinois river at Grafton, is usually in a condition very similar to that obtaining at Averyville. Peoria is about 124 miles from Kampsville and Averyville is about 130 miles from Lockport. During this entire period my chemical and bacterial examinations do not disclose the presence at Kampsville of the sewage from Chicago whether from the Illinois and Michigan canal for the first part of this period or from the Chicago main drainage canal for the second, so far as the number of bacteria in the water is concerned,

5969 nor do they, so far as the various chemical determinations of albuminoid ammonia, oxygen consumed, nitrites and nitrates are concerned. The large amount of chlorine that enters the Des Plaines river along with the Chicago sewage, is,

however, permanent, and not being liable to destruction by various influences, as is the case with the nitrogenous organic matter and the bacteria, that are added in the Chicago sewage, the chlorine manifests itself at Kampsville and Grafton, and even beyond, into the Mississippi river.

Q. Does the presence of chlorine in the water of a river in the absence of the other chemical ingredients or constituents of sewage indicate of itself the presence of sewage pollution?

A. In my opinion the presence of chlorine under those conditions would be absolutely devoid of sanitary significance. It would be possible for a stream in the condition that the Illinois river was in at Kampsville, to be passed around the world several times in a closed conduit, consuming years or decades in the process, without altering materially the amount of chlorine in the water, although it is my judgment that, supposing the water were at the outset injurious to health, in the course of such a passage and in such a time, it would become entirely free from any injurious qualities it might have originally possessed.

I prepared five charts based upon the analytical tables for this period, concerning which I have testified. The first one is designated, "Chlorine, parts per million, in the Illinois river, Edwin O. Jordan," and is reproduced on page 5971.

5972 This chart is a diagramatic representation of the averages of the chlorine determination for May and June, 1899 and for May and June, 1900, the amount of chlorine being plotted in numbers per million and the miles along the course of the Illinois river being indicated at the foot of the chart.

The solid line representing 1899 period.

The broken line representing the 1900 period.

The diagram shows that the large amount of chlorine present at Lockport during May and June, 1899, and May and June, 1900, is diminished by dilution with the water of the tributaries which are less highly laden with chlorine during the progress of the river from Lockport to Gafton.

The curves for the two periods follow substantially the same course. The greater dilution of the water in the upper stretches of the river during May and June, 1900, being shown by the smaller amount of chlorine at Morris and Ottawa for example. In the lower part of the river such dilution as occurred during these periods is apparently about balanced by the additional amount of chlorine in the river.

5974 The chart, reproduced on page 5973, designated by the heading "Albuminoid ammonia, parts per million, Illinois river, Edwin O. Jordan," is a graphic representation of the amounts of albuminoid ammonia in the water of the Illinois river at different points for May and June, 1899, and for May and June, 1900.

Unlike the chlorine, the albuminoid ammonia is not permanent, but undergoes certain changes in its passage down the stream. The curves for May and June, 1899, and May and June, 1900, follow like the curves for chlorine, a substantially parallel course, but the May and June determinations for 1900, are somewhat lower throughout the whole stretches of the river than for May and June, 1899.

Reference to the chlorine chart already offered in evidence, will show that this is not so with the chlorine, so that so far as these determinations go, there has apparently been a greater purification based on the decomposition of albuminoid ammonia in May and June, 1900, than in May and June, 1899.

5976 The chart, reproduced on page 5975, designated as "Free ammonia, parts per million in the Illinois river, Edwin O. Jordan," is a graphic representation of the averages of the free ammonia determinations for May and June, 1899 and for May and June, 1900.

The effect of increased dilution in the upper stretches of the river is evident here as in the case of the albuminoid ammonia and chlorine. In the lower half of the river the amount of free ammonia was somewhat greater in May and June, 1899, than in May and June, 1900. This condition coincides more

closely with the condition shown in the chart of albuminoid ammonia than in the chart of chlorine.

5978 The chart, reproduced on page 5977, designated "Number of bacteria per cubic centimeter at Grafton," is a graphic representation of the number of bacteria as determined by weekly determinations in May, 1899 to the end of June, 1900. The full line representing the number of bacteria in the Mississippi river at Grafton, and the broken line representing the number of bacteria in the Illinois river at Grafton.

Throughout May and June, 1899, and to a lesser extent in July and August of this year, both rivers had a high bacterial content. This condition was followed by relatively small numbers of bacteria in both rivers through September, October and November, a condition that was followed in December, by a sudden and notable increase in the number of bacteria, and then by a period of irregular step-like ascent in both cases, amounting in March, 1900, to an exceedingly high point. This was followed by a rather abrupt decline in the numbers of bacteria until in May and June, 1900, the numbers were very similar to those in July and August of 1899.

5980 The diagram, reproduced on page 5979, designated, "Number of bacteria per cubic centimeter in the Illinois river, Edwin O. Jordan," is a graphic representation of the average numbers of bacteria for May and June, of 1899, and May and June, 1900, starting at Lockport with high initial numbers in both cases.

The number of bacteria drops to a relatively low point in the neighborhood of Ottawa, continuing low to Averyville, below that point, showing a very notable increase, especially during the first period, apparently due to the pollution of Peoria. As with the initial pollution the numbers of bacteria introduced at Peoria diminish, and for the last stretch of 120 miles the numbers of bacteria are very similar to those found at Henry and Averyville above Peoria.

The increase in numbers of bacteria at Wesley City below Peoria is apparently much less in May and June, 1900, than in

May and June, 1899. This however is probably apparent rather than real and is due to the fact that the sample which was collected in mid-stream at Wesley City, did not give as definite indication of the addition of Peoria sewage as was the case in the 1899 period, since the greater body of water in the Illinois river at this time probably crowded the pollution towards the western bank.

5981 Witness gives distances from Bridgeport in miles as follows:

5982

| | | |
|---|---|---|
| Lockport, | 29 | miles. |
| Joliet, | 33 | do. |
| Morris, | 57 | do. |
| Ottawa, | 81 | do. |
| La Salle, | 95 | do. |
| Henry, | 123 | do. |
| Averyville, | 159 | do. |
| Wesley City, | 165 | do. |
| Pekin, | 175 | do. |
| Havana, | 199 | do. |
| Beardstown, | 231 | do. |
| Kampsville, | 288 | do. |
| Grafton, | 318 | do. |

5983 An attempt is made to indicate the less complex condition of these nitrogenous bodies by smaller and less intricate spirals. The oxidation of the free ammonia to nitrites being in turn oxidized to the completely mineralized nitrates, which with carbon dioxide, water and other substances devoid of available potential energy, occupy the region of complete mineralization at the bottom of the circle.

Various forms of plant life are able with the aid of sunlight to utilize hte nitrogen of the nitrates as food; and through stages of ever increasing complexity, the exact nature of which is unknown, the nitrates are built up again, into the living bodies of plants and animals, and become again organic nitrogen, from which point the nitrogen eventually starts anew on its cycle.

Owing to the effect that the occurrence of nitrogen in the form of organic nitrogen and as free ammonia is associated with the decomposition of substances discharged from the bodies of animals, the presence of nitrogen in these forms indicates relatively recent contamination with organic matters, while owing to the time that must elapse for the process of nitrification to be completed, the occurrence of nitrates in inconsiderable abundance in surface water is taken as indicating that a relatively long period has elapsed since original contamination took place.

In such a water as the Illinois river, the nitrogenous matter introduced in the Chicago sewage may pass through this complete cycle several times on its way to the mouth of the river. The oxidation of the organic nitrogenous compounds introduced into the river at Lockport may take place under certain circumstances in the upper stretches of the river. The nitrates thus formed may be utilized by microscopic algae for building up their life substances, and thus again pass into the state known as organic nitrogen or albuminoid ammonia. From the advent of cold weather, or from other unfavorable circumstances these organisms may die, and the nitrogen composing their bodies being again decomposed, may reach
5984 the mineralized form of nitrate and perhaps again begin the upward part of the cycle.

Under certain circumstances, any river into which an excessive amount of nitrogenous matter is emptied, will contain throughout a large part of its course, an amount of nitrogen in one form or another, in excess of that existing in a stream not so laden at the start. Under such conditions the appearance and reappearance of nitrogen as free ammonia, albuminoid ammonia, or one or another of these compounds, cannot be held to possess the same sanitary significance as under some other conditions.

Free ammonia at the mouth of the Illinois river for example, may be derived from a decomposition of algae, while free ammonia at Lockport or Bridgeport may be derived from

decomposition of waste substances leaving the human or animal body, or discharged into the water in the course of various manufacturing operations.

This diagram I think, serves to illustrate some of these points and to show the complexity of the phenomena attending the decomposition of organic compounds containing nitrogen, and the re-composition of this nitrogen in the bodies of other living forms.

I made hourly bacterial surveys of the water of the Illinois below Morris, between Morris and Ottawa, at Wesley City, and at Grafton.

Taking first the determinations made on the Illinois river at Morris. Several series of observations were carried out at this point. The first of these was on October 7th, 1899. The day was bright and sunny, the temperature of the air being 7 degrees centigrade at six o'clock in the morning, and reaching 20.5 by mid-day. A slight breeze ruffled the surface of the water in the middle of the day, but was at no time strong. The river was very low, the gauge reading for that day being five feet, and the current exceedingly sluggish.

5985 With a view to determining the distribution of bacteria indifferent portions of the Illinois river at this point, a cross section was taken across the river from the right to the left bank; three samples being taken at approximately equi-distant intervals from one another and from the shores. The upper cross sections were taken at a point just above the Mazon river, the lower about three-quarters of a mile below the mouth of the Waupecan Creek. This was at a dry period, and little if any water passed into the Illionis from these tributaries at this date. This stretch of river is almost exactly three miles in length. The rate of flow between the two points was determined by weighted floats and by the use of fluorescein solution, and was found to be very close to half a mile per hour.

Four series of cross sections at hourly intervals were taken at the upper station, which may be designated as Station A, and these were followed by similar series at the lower station,

Station B, beginning six hours later. These samples were plated immediately after the collection, the plating being completed within the hour in each case.

At Station A the river was about 150 yards wide, and at Station B about 125.

The figures given for the number of colonies in the tables that follow are the averages of counts of two separate platings.

These tables reproduced on page 5986 *et seq.*

5986 Attention may be directed to the fact that between these collecting stations, a distance of three miles traveled by the stream on this date in about six hours, a great bacterial diminution occurs. The chlorine determinations show that the mixing of the Kankakee water and the Des Plaines water is very incomplete both at the upper station which is about nine and one-half miles below the junction of the rivers, and at the lower station as well. This is entirely confirmed by the bacterial count and turbidity cross sections at the two points.

It should be noted that the decline in the numbers of bacteria occurs in almost equal degree throughout the whole breadth of the stream, being as great along the highly polluted right bank of the river as along the comparatively incontaminated left bank.

A second series of observations was carried out on November 9th, 10th and 11th, 1899, in similar fashion, upon a longer stretch of river. The distance between the regular collect-

5987 ing station at Morris and the regular collecting station at Ottawa is about 24 miles, and the rate of flow between these points averaged one-half a mile per hour at the time our observations were made. A point midway between Morris and Ottawa was selected, near Seneca, and a three days series of operations was planned. The sun was wholly obscured by clouds during these three days, but no rain fell. The results are given as before in tabular form.

Figures are given for the upper station at Morris, the middle station at Seneca and the lower station at Ottawa, the averages being reproduced on page 5988.

5988 The averages are as follows:

| | Distance from Morris. | No. Colonies per c. c. Right Bank. | Center. | Left Bank. | No. of Hourly Analyses. |
|---|---|---|---|---|---|
| Upper Station (Morris)..... | ..... | 261,000 | 204,000 | 29,000 | 3 |
| Middle Station (Seneca)..... | 12 miles. 24 hours. | 100,000 | 49,000 | 35,000 | 2 |
| Lower Station (Ottawa) ..... | 24 miles. 48 hours. | 11,500 | 10,700 | 13,500 | 2 |

During this flow of 24 miles therefore, the Illinois river became nearly free from the great mass of sewage bacteria with which it was originally laden. In fact the bacterial content of the Illinois at Ottawa on this date was not greatly in excess of that of the local tributary streams.

In connection with this series of bacterial determinations may be given the averages of the regular chemical determinations made at the laboratory in Chicago during the period between October 23d and November 20, 1899. These determinations, which follow, show that a considerable degree of nitrification takes place in the river between these two points, as witnessed by the increase in the amount of nitrites and nitrates, the diminution in free and especially in the albuminoid ammonia.

| | | Residue on Evaporation. | | | Oxygen Consumed. By Dissolved | By Suspended |
|---|---|---|---|---|---|---|
| Station. | No. Determinations. | Total. | Dissolved. | Suspended. | Total. | Matter. | Matter. |
| Morris ..... | 5 | 398 | 380 | 18. | 10.7 | 8.4 | 2.3 |
| Ottwa..... | 5 | 356 | 353.5 | 2.5 | 7.5 | 7.3 | .2 |

| | Nitrogen as Albuminoid Ammonia. | | | | |
|---|---|---|---|---|---|
| Free Ammonia. | Total. | Dissolved. | Suspended. | Nitrites. | Nitrates |
| 7.98 | .860 | .478 | .382 | .028 | .340 |
| 6.6 | .364 | .315 | .049 | .382 | .648 |

A third series of similar observations was made between these same points on May 24th, 25th and 26th, 1900. The sun was partially obscured on May 25th, but shone brightly on May

24th and 26th. No precipitation occurred during the period.

5989 The results are shown on pages 5988 and 5990 in tabular form.

5990 This last series of determinations shows that on May 24th, 25th and 26th, 1900, the mixing of the Kankakee and Des Plaines rivers at Morris was more complete than on November 9th, 10th and 11th, 1899. They also show a smaller number of bacteria per cubic centimeter of the water at this time. A diminution in the numbers of bacteria, however, similar to that noted in the earlier series takes place during the cubic centimeter as shown by the colony count at Ottawa during this period in 1900, than in November, 1899.

5991 I see no escape from the conclusion that in this flow of approximately 24 miles, the Illinois river which at Morris contained a large number of bacteria in all probability derived more or less directly from the sewers of Chicago freed itself from these bacteria to a remarkable and impressive degree in a short distance and, in a relatively short space of time. The probable reason for the high mortality among bacteria in this particular stretch of the river will be discussed in another connection.

I should like to state that these three series of observations upon the water of the Illinois river between Morris and Ottawa are not the only series that I have made between May, 1899 and June, 1900.

I have made several other series of observations between Morris and Ottawa of the same character as those just described. The samples were collected in the same way, the experiments in each case being conducted by my chief assistant, Mr. Irons, and myself.

Between July, 1899 and June, 1900.

**Between Morris and Ottawa.**

One of these was on September 2, 1899. I have memoranda of the others with my papers at the University.

5992 One of these, of which I have a record here, was made on June 13th, 1900. It gave the following result:

| | Free ammonia. | Albuminoid ammonia. | No. of colonies per c. c. |
|---|---|---|---|
| Right bank, | .504 | .864 | 4,340,000 |
| Center, | .144 | .248 | 40,000 |
| Left bank, | .168 | .240 | 2,400 |

This cross-section was not made by me personally, but by Mr. Irons, in pursuance of my directions.

The large amount of pollution entering the river at Peoria on the right bank of the river is clearly shown in this sample. The free ammonia, the albuminoid ammonia, and the number of bacteria per cubic centimeter being immensely greater than on the left bank of the stream. Slight changes in the position of sand-bars and in the height of water deflect the main mass of pollution now to one side, of the the stream, now to the other, and so lead to the sudden and marked fluctuations in the analyses which the detailed tables show to be so characteristic of the samples obtained from this point.

Yes, on a number of occasions both in 1899 and in 1900, cross-sections were taken of the Illinois river at Grafton. These cross-sections at Grafton dealt simply with the number of bacteria per cubic centimeter. In general it may be said that the results obtained from samples taken midway between the banks of the streams and the center were not materially different from those taken from the center of the stream, mixing of the bacteria, so far as these determinations go, being complete at this point. Slight variations were however, sometimes no-

5993 ticed, the number being sometimes higher in the center than on the sides; sometimes higher on the sides than in the center.

These observations upon the bacterial content of the Illinois river between Morris and Ottawa indicate in my judgment that a very large proportion of the bacteria entering the Des

Plaines river from the Illinois and Michigan canal and from the Chicago drainage canal do not survive to reach Ottawa. From a sanitary point of view this observation would seem to be of importance in that it renders less probable the passage of disease germs down the river, as far as this point. Since these sewage bacteria disappear in such numbers, it is my opinion, fair to assume that the various non-spore forming pathogenic bacteria entering the Chicago sewage, die out at least in the same proportion.

5994 In giving the last opinion I am of course obliged to take into consideration all the knowledge that I possess on the life of pathogenic germs and their relation to sewage bacteria. I regard however, these observations upon the bacterial content of one and the same body of water as reinforcing in a remarkable manner all that I have been able to learn in other ways regarding the life of bacteria introduced into water with sewage. I made determinations for the bacillus coli communis. There were several series, the first covering a period between May, 1899, and June, 1900. (Witness states points at which these determinations were made, ranging from Lockport to the

5995 tap water at St. Louis.). I have a list of tables prepared showing bacilli coli communis determinations. (Witness gives characteristics of that bacillus, also states relationship of bacillus coli communis to the bacillus typhosus and some of the main points of differentiation between those two germs.

These are some of the fundamental distinctions between

5996 these two germs. The colon bacillus is in every respect more hardy than its near relation the bacillus typhosus.

In comparative tests that have been made on the relative viability of the bacillus coli and the bacillus typhosus under certain conditions, the following facts have been demonstrated:

1. As regards sand filtration with the water to which both species have been added, 99.9 per cent of all the bacillus coli and 100 per cent of the bacillus typhosus were removed by an intermittant filter, and 99.8 per cent of bacillus coli and 99.9 per cent of bacillus typhosus by a continuous filter.

2. As regards the persistence of the two organisms in a filter after infection of the applied water has ceased, bacillus coli was found to continue in the effluent from the intermittent filter for 24 to 36 hours, and the bacillus typhosus only for two to three hours. With the continuous filter the bacillus coli continued for 46 days, and the bacillus typhosus for 2 days.

5997 3. The effect of cold without freezing. In a water subjected to a temperature of 33 degree Fahrenheit, about 90 to 95 per cent of both species were destroyed within 24 hours. A few organisms of each, however, may live for a considerable number of days.

4. Elimination by freezing and viability in ice. About 50 per cent of the bacillus coli and 75 per cent of the bacillus typhosus, were destroyed by fifteen minutes freezing, after one hour, 95 per cent of the bacillus coli and 98 per cent of the bacillus typhosus were killed, and at the end of 24 hours over 99 per cent of all the organisms had disappeared.

5. Resistance to heat. Both species resisted temperatures up to 45 degrees for five minutes. And between 45 and 55 degrees centigrade, all but a few individuals of each are destroyed. These few individuals however, resisting temperature up to 85 degrees centigrade, at which temperature all organisms of both species were destroyed.

As bearing further on the question of the relative resistance of these two organisms I may state that some experiments were made by me some years ago a report of which is printed in the Medical News on September 28th, 1895, in which it was found that the typhoid bacillus when introduced into sterilized Lake Michigan water, does not multiply, but may under certain conditions, maintain its vitality for upwards of 93 days. The colon bacillus on the contrary, under the same conditions, undergoes rapid multiplication and may remain alive for upward of 263 days.

6000 From the facts just enumerated, it is clear that while the colon bacillus resembles in many important particulars the typhoid bacillus, it is under all conditions in which the via-

bility of these two organisms has been compared a more hardy and more resistant organism. Its longevity under adverse conditions is greater than that of the typhoid bacillus. This fact, and the ease with which it is isolated and identified, combine to render it a particularly significant organism from a sanitary point of view.

6001 Witness gives illustration through experiment made by Dr. Bissell of Buffalo, New York, and states that this illustration suffices to show that it is possible by means of the delicate test for colon bacilli to detect a degree of pollution which might be altogether missed by the use of less delicate and less precise methods.

So far as I have been able to discover, it is at the present time, the prevailing opinion among those bacteriologists who deal with sanitary water analysis that the test for the colon bacillus properly applied and interrupted, furnishes one of the most satisfactory clews to the sanitary condition of a water.

In this connection it should be emphasized that it is not so much the presence or absence of bacillus coli communis in a large quantity of water that is significant as it is the relative abundance of this micro-organism.

Witness then refers to various scientific authorities on the subject of the importance of the bacillus coli communis test as a determination of the pollution of water. The witness also quotes from various works on this subject.

6005 Witness states method employed by him in determinations made for the bacilli coli communis.

6007 In support of my opinion as to the value and importance of the presumptive test for the presence of the bacillus coli in water, I may cite some conclusions in a paper by Mr. George C. Whipple, of Brooklyn, who I understand has already testified as a witness in this case. The paper is entitled "On the Practical Value of Presumptive tests for Bacillus Coli in Water." It was printed in the "Technology Quarterly, published at the Massachusetts Institute of Technology," volume 16, No. 1, March, 1903.

"The methods necessary for the certain identification of bacillus coli in water involved technique so complicated and so time consuming that they are not practical as working tests in connection with the supervision of water supplies.

2. The fermentation of Dextrose broth as first suggested by Dr. Theobald Smith, furnishes the most rapid and most practical test for the presence of bacillus coli in water.

3. The extension of this test to cover different quantities of water in the same samples, thus making the test quantitative, within limits as well as qualitative, greatly enhances its value.

4. But whether or not bacillus coli is simply an intestinal germ, the fermentative test described above is a useful test to determine the sanitary quality of water and is one which gives results that agree well with chemical and biological analyses."

At another point in this same paper, page 22, Mr. Whipple says:

"Speaking broadly the typical reactions offer satisfactory presumptive evidence of the presence of this species (B. coli-communis) or species very closely allied to it. In a subsequent paper I hope to give the data to support this assertion, but at this time will offer as corroborative testimony, the statement of Mr. Irons, who in his paper on some observations of methods for the detection of the bacillus coli communis in water, states:

"When the Dextrose tube yields approximately 33 per cent of carbon dioxide, bacillus coli communis is almost invariably present."

6008 From all my experience upon the value of presumptive tests for B. coli, I am obliged to believe that this test is of high value in sanitary water analysis, and enables conclusions to be drawn as to the presence or absence of the colon bacillus which are in the main thoroughly satisfactory and decisive. The table of chlorine determinations which I have prepared cover a period of time between May, 1899, and the end of June, 1900. These determinations were made from the bacteriological samples collected by the same water takers and at the same time as heretofore specified in my testimony. (Witness then states

places at which samples of water were taken, and determinations made.)

6009 Table No. I, Illinois and Michigan canal at Lockport, read in evidence.

6010 The table shows that in this highly polluted water, the bacillus coli was occasionally present in so small an amount of water as .0001 of a cubic centimeter, and that it was usually present in so small an amount of water as .0001 of a cubic centimeter. Table No. I-B, Drainage canal at Kedzie avenue.

6011 The greater dilution of the sewage in the drainage canal during this period as compared with the condition of the Illinois and Michigan canal shown in Table I, is manifested by the comparatively rare occurrence of the colon bacillus in .0001 of a cubic centimeter of water, and its occasional absence, even when .001 of a cubic centimeter of the water was examined.

Table No. I-C, Drainage canal at Lockport. The dilution shown in the drainage canal, at Kedzie avenue, is shown also in the drainage canal at Lockport, the colon bacillus being present in all the samples of .1 of a cubic centimeter that were examined and in many of those of .01 of a cubic centimeter, but being almost invariably absent where .001 of a cubic centimeter

6012 was examined. Table No. II contains the results of colon determinations made upon the water of the Des Plaines river between August 1st and November 28, 1899.

Q. On page 150 of his testimony, Dr. Ravold testified that the colon bacillus was found in 72 per cent of the samples taken from the Bear Trap dam at Lockport in the month of March, 1900, and at page 320 of his testimony, he testified that the bacillus coli communis was found in 71 per cent of the samples

6013 collected from the St. Louis settling basins during the period from May 1st to October 31, 1900. Would you infer from those statements that colon bacillus was present in the water of these settling basins in St. Louis in anything like the same proportion that it was in the water of the drainage canal at Lockport?

A. I certainly should not. (Witness gives reasons for his answer and on page 6014 states:) I am compelled to assume that the statements to which you refer are based on defective analytical methods, and do not indicate that the actual number of colon bacilli in the water of the drainage canal and in the St. Louis settling basins are at all comparable. Table No. III, Kankakee river at Wilmington. This table shows that between August 7th and November 20th, 1899, the colon bacillus was frequently present in .1 of a cubic centimeter, and usually present in one cubic centimeter.

6015 Table IV, Illinois river at Morris. This table contains
6016 the results of colon determinations made upon samples of water taken from the Illinois river at Morris between October 31, 1899, and June 27, 1900. They show that during the early part of this period the colon bacillus was generally present in .001 of a cubic centimeter of the water, while in the latter part of this period, namely from January 30, 1900, to April 23, 1900, it was rarely present in this dilution. In fact in May and June, 1900, the colon bacillus was even absent in quantities of .01 of a cubic centimeter, and occasionally absent in quantities of .01 of a cubic centimeter, and occasionally absent in .1 of a cubic centimeter sample.

6017 Table V, Fox river at Ottawa, contains the results of colon determinations made upon samples of water taken from the Fox river at Ottawa between August 1st, 1899, and June 26, 1900. They show that in this water, the colon bacillus was rarely present in .1 of a cubic centimeter; was often present in one cubic centimeter and usually present in five cubic centimeters of water.

6018 Table VI, Illinois river at Ottawa shows that during the
6019 greater part of this period, colon bacillus was occasionally present in .01 of a cubic centimeter, and that it was frequently present in .1 of a cubic centimeter.

Table VII, the Big Vermilion at La Salle. The colon bacillus was commonly absent in .1 of a cubic centimeter of water

and found only about half of the time in one cubic centimeter samples.

6020 Table VIII, Illinois river at La Salle. The number of colon bacteria found here corresponds very closely with the number found in the Big Vermilion river, it being noted that the samples were taken at these two points on the same dates.

Table IX, Illinois river at Henry, contains results of

6021 colon determinations made upon samples of water taken between June 7, 1899 and January 17th, 1900.

Table X, Illinois river at Averyville.

6022 The relatively large number of colon bacteria present in the Illinois river at Morris as shown by Table IV has been greatly diminished between Morris and Averyville, so that while at Morris the colon bacillus was found almost invariably in .1 of a cubic centimeter of water, at Averyville it was but rarely present in this amount of water, and occasionally absent even in one cubic centimeter of water. This group of organisms appears to have suffered a great mortality in the water between Morris and Averyville.

6023 Table XI, Illinois river at Wesley City.

6024 The increased pollution of the river at this point is shown by the swollen number of colon bacilli, which were found quite often in .1 of a cubic centimeter of water. Table XII, Illinois river at Havana. The colon bacillus was commonly present in one cubic centimeter of water.

6025 Table XIII, Sangamon river at Chandlerville.

6026 As before stated, the Sangamon river receives above Chandlerville, the sewage of a very considerable urban population, and this condition is reflected in the relatively high number of colon bacilli, which during the period covered by these determinations, range much higher than the number found in the water of the Illinois river at Averyville, as evidenced especially by the determinations made of .1 of a cubic centimeter samples. The colon bacillus was even found occasionally

in .01 of a cubic centimeter of water taken from the Sangamon river at this point.

6027 Table XIV, Illinois river at Grafton.

6028 The colon bacillus was present in .1 of a cubic centimeter samples in about the same proportion as at Averyville, and was present in the majority of one cubic centimeter samples, as is usually found to be the case with unprotected surface waters receiving at more or less frequent intervals the drainage of urban and rural communities.

6029 Table XV, Mississippi river at Grafton.

6030 The colon bacillus was found during this period not infrequently in .1 of a cubic centimeter samples, and in the majority of one cubic centimeter samples, being in this respect like the Illinois river, a typical unprotected surface water.

6031 Table XVI, Mississippi river cross-section at Alton.

6033 Table XVII, Missouri river, West Alton.

6034 During this period the colon bacillus was found quite commonly in .1 of a cubic centimeter of water, especially in the months of May and June, 1900, and was commonly present in the one cubic centimeter of water samples. Table XVIII, Mississippi river, intake tower, St. Louis waterworks,

6035 Mitchell. The results show a general similarity with those obtained from the water of the Missouri river at West Alton. Table XIX, St. Louis tap water. The smaller number of colon bacteris in .1 of a cubic centimeter samples, as compared with the number found in the Mississippi river, at the water intake, indicates a considerable diminution in the number of colon bacteria during the passage through the settling basins and water pipes. I have a table of summaries of results for the principal stations in the Illinois river. This table is reproduced on page 6036, and it summarizes the results obtained from the colon determinations made upon the waters colected at the principal stations along the Illinois river. It shows that in the water of the Illinois and Michigan canal at Lockport the bacillus coli was present in .001 of a cubic centimeter of water on

28 days out of 32 days on which examinations were made. It shows further that in the water of the Illinois river at Morris the colon bacillus was present in .01 of a cubic centimeter of water on 20 days out of 30 days on which examinations
6037 were made, while at Ottawa it was present in the same quantity of water on only 6 days out of 22 days on which examinations were made.

At Ottawa the colon bacillus was found in .1 of a cubic centimeter of water on 19 days out of 34 days on which examinations were made, while at Averyville it was found in the same quantity of water on only 5 days out of 27 days which examinations were made.

The increased pollution of the water at Wesley City is shown by a larger number of colon bacilli as indicated by the fact that the colon bacillus was found in .1 c.c. of water from this point on 13 days out of 26 days, on which examinations were made, or more than three times as frequently as in the Illinois river at Averyville above Peoria.

At Grafton at the mouth of the river the colon bacillus was found in .1 of a cubic centimeter on 13 days out of 35 days on which examinations were made.

These summaries show that the colon determinations coincide with the results of the routine chemical and bacterial examinations already referred to.

The processes of oxidation of the organic matter, the death of the mass of sewage bacteria and the mortality among the specially significant group of colon organisms appear to run a closely parallel course, and the inference as to the purification of the stream drawn from the chemical analyses and from the count of bacterial colonies, is further emphasized by the mortality shown to occur in this significant class of sewage bacilli.

6038 Table reproduced on this page, which contains a summary of the results of the colon determinations made upon the Illinois river at Averyville and Grafton, compared with

the tributaries of the Illinois and with the Mississippi and Missouri rivers.

On comparing the number of days on which bacillus coli was found in one cubic centimeter, samples of water taken from the Illinois river at Averyville, with those taken from the Illinois river at Grafton, from the Mississippi river at Grafton, from the Des Plaines river, from the Kankakee river; from the Fox river, from the Big Vermilion river; from the Sangaman river, and from the Missouri river, it appears that so far as the colon content enables one to pass an opinion as to the sanitary quality of these waters the Sangamon river at Chandlerville, is one of the more highly polluted streams.

The Illinois river at Grafton, the Mississippi river at Grafton and the Missouri river at West Alton appeared to be
6039 on substantially the same footing with one another in respect to their colon content, while the Fox river contained a smaller proportion of colon bacilli than any of the streams under consideration.

The Illinois river at Averyville compares in respect to its colon content very favorably with the Illinois, Mississippi and Missouri rivers and is perceptibly less highly contaminated than the water of the Sangamon river at Chandlerville.

Summing up these facts in the second division of this table it is seen that samples of water taken on 69 different days from the Illinois river at Averyville and at Grafton contained bacillus coli communis on 39 days, while the various tributaries of the Illinois river, samples from which were taken on 69 days, contained colon bacillus on 36 days. Samples taken from the waters of the Missouri on 66 days contained colon bacillus on 44 days.

It appears therefore from these tables, that if the opinion that I have expressed regarding the sanitary significance of the colon bacillus in water is correct, the water of the Illinois river at Averyville and Grafton was not materially different from what it would have been if the tributaries of the Illinois, exclusive of the Des Plaines river and its sewage content, had

alone fed the basins of this stream. The colon content of such a stream at Averyville and at Grafton would have been substantially what it is at present.

As stated in my testimony of yesterday, my experience leads me to adopt the view that the relative abundance of the colon bacillus in water affords the most satisfactory single analytical indication that sanitary science at present possesses as to the sanitary quality of a natural water.

Basing my opinion upon this I may say that I regard the relative abundance of colon bacilli in the water of the Illinois river at various points, and in the various tributary streams as furnishing a highly important clew to the freshness of the pollution entering, and the amount of real purification undergone by each stream. Considered from this standpoint the water
6040 of the Illinois river at Averyville and at Grafton, is no more impure than the water in the principal tributaries of the Illinois, and certainly no more impure or dangerous than the water of the Mississippi river at Grafton, or the Missouri river at West Alton. The successive and striking diminution in the number of colon bacilli at various points along the Illinois river from Lockport to Averyville, is proof in my judgment of the occurrence of a process of genuine self-purification.

I regard these determinations as forming a connected and correlated whole, mutually sustaining one another, and all pointing in my judgment, to but one interpretation. The oxidation of the organic matter that was introduced in enormous quantities at Lockport, the more or less complete destruction of sewage bacteria also introduced at this point, and especially the high mortality among the colon bacteria occurring in the upper stretches of the river, all appear to me to indicate that infectious matters that might have been introduced into the sewage of Chicago and found their way into the drainage canal during this period from May, 1899 to the end of June, 1900, did not make their way down river so far as Averyville. So far as my interpretation of the results of the chemical analyses, the bacterial counts and the colon determinations is concerned, I have no hes-

itation in expressing as my opinion that the water of the Illinois river at its mouth is no more liable to convey disease or to produce injurious consequences of any kind than the waters of the Mississippi river at this point, or the water of the Missouri river at West Alton. In expressing this opinion I am taking into consideration all the knowledge that I have acquired by personal experience and all the information that I have obtained regarding the chemical and bacterial content of these waters during the period under consideration.

6041 I made a survey of the waters of the Illinois, the Mississippi and the Missouri rivers in 1901. So far as I understand these circumstances, an agreement was reached between the authorities of the State of Missouri and the State of Illinois, for conducting a joint investigation of the water of the rivers named, at certain points. The aim of this joint examination was, as I understand it, to secure that the samples should be taken at specified places, at specified times, and under uniform conditions. Witness states in whose charge the various laboratories were, the nature of the work carried on, the points where samples of water were collected for examination in these three different laboratories, the instructions given for the plating of these samples relative to the time of collection, and states

6043 on page 6043 that the work done during this period was wholly bacteriological in character and may be grouped conveniently under three heads:

(a) The determination of the number of bacteria in the river water as shown by the ordinary colony counts.

(b) The number of germs of the colon group in the river water as shown by the Dextrose fermentation tube test.

(c) Study of the species of bacteria isolated from the river water.

The first two determinations were carried out in the respective branch laboratories, and it is certain that a decided gain in the accuracy of the results was attained by conducting this work at or near the points of collection, upon freshly collected samples, instead of allowing as in the previous work, a consider-

able interval to elapse while samples were being transported to a distant point. The detailed study of the bacterial species was carried out under more advantageous conditions offered for this kind of work by the University laboratories.

Witness states the method employed in making all these determinations.

6044 I have the tables prepared at the different stations where these determinations which I have just described were made.

6045 MR. TODD: I offer the original analytical report from the laboratory at St. Louis made by W. G. Sackett, that at Grafton made by W. S. Sayer, and that at Peoria made by F. W. Schule, to Professor E. O. Jordan of the Chicago University, under whose direction and supervision these analyses were made. Also the coli determinations made by the same parties at the three different laboratories for this period and reported to Professor Jordan in the same manner as above indicated. These reports are offered for the inspection of counsel and will be made a part of the evidence if objection is made to their non-introduction.

Two sets of tables were made of the determinations at Peoria, one covering the samples of water collected at Averyville; the other covering those collected at Pekin. Table for the determination made at Averyville, in the Peoria laboratory, read in evidence on pages 6046-7-8-9.

This table contains the results of daily bacterial determinations made upon samples of water from the Illinois river at Averyville between October 9th and December 30th, 1901. On this table are specified the date of collection, the hour of collection and the hour of plating, the temperature in degrees centigrade of the water and air; the height of water; the dilution in which the sample was plated, the number of colonies

per cubic centimeter (two samples in most cases) and the average of these daily determinations. Throughout October
6050 and November the numbers of bacteria in the water as shown by the colony count were low; the counts showing often only a few hundred colonies per cubic centimeter. In December the numbers increased somewhat and in the latter part of December, the numbers are on several occasions in the tens of thousands.

So far as the bacterial count is concerned, these examinations show that the water of the Illinois river at this point was in a condition which considered as a river water, was fully up to the average of river waters in this country.

On pages 6051-2-3 is reproduced table showing determination made at Peoria laboratory for the point at Pekin.

6054 This table shows the result of colony counts made from samples of water collected from the Illinois river at Pekin between October 16th and December 13th, 1901, the same data being given as in the table for Peoria.

Throughout this period this water is characterized by a much higher bacterial content than the water of the Illinois river at Averyville. On October 26th, for example, the average number of four determinations at Pekin was 341,000, per cubic centimeter, while at Averyville on the same date there were only 890 colonies per cubic centimeter.

Table read in evidence showing determination made of
6059 the Illinois river at Grafton. This table contains the results of bacterial counts made from samples of water taken from the Illinois river at Grafton between October 1st and December 24, 1901. The data specified as given in the Peoria tables are given also in this table. The numbers of bacteria per cubic centimeter found in the water of the Illinois river at Grafton are very similar to those found in the water of the Illinois river at Averyville.

Table read in evidence showing determination made of the Mississippi river at Grafton.

6064 This table contains the tabulations of colony counts made from samples of water obtained from the Mississippi river at Grafton between October 1, 1901, and December 24, 1901, other data specified in the Peoria tables being also included in this table. Throughout most of the period covered the results correspond rather closely with those obtained upon the Illinois river at its mouth. Tables for the cross section of the Mississippi river at the Chain of Rocks read in evidence. These tables contain tabulations of colony counts made from samples of water taken from the Mississippi river at the Chain of Rocks between October 7, 1901, and December 14, 1901, at four points across stream, namely, those specified in the records of the cross section at this point for 1899 and 1900. These tables show that throughout the period covered the number of bacteria contained in the water taken from the Mississippi river at the intake tower, and from the Missouri shore contained a noticeably larger number of bacteria than the water on the Illinois shore.

6077 Tables read in evidence showing colony determinations from the Missouri shore at Fort Bellefontaine.

6080 This table contains tabulations of colony counts made from samples of water collected from the Missouri river at Fort Bellefontaine between October 9th and December 16th, 1901; other data being included as hereinbefore specified. It shows that throughout this period the number of bacteria in the water of the Missouri river at this point was noticeably higher than in the water of either the Illinois river at its mouth, or the Mississippi river above Grafton.

6081 Tables of averages from the table just read, read in evidence.

This table contains the averages of the colony counts made from the waters of the Illinois river at Averyville, at Pekin and at Grafton; from the Mississipi river at Grafton, and in cross section at the Chain of Rocks, and from the Missouri river at Fort Bellefontaine. The number of bacteria found at Avery-

ville and at Grafton was not dissimilar. These averages were higher than the average for this period in the Mississippi river. The usual winter increase which occurs in river waters took place this year in the Illinois river before making its appearance in the Mississippi. Up to the middle of December, 1901, the two waters were very similar as regards their bacterial content. Throughout the whole of the period studied, the average number of bacteria as shown by the colony count in the water of the Missouri river at West Alton was several times as great as the water in either the Illinois river at its mouth or the Mississippi river above Grafton. The number of bacteria in the Illinois river at Pekin as shown by these averages was greatly in excess of that found at any other of the collecting stations, as in my opinion naturally follows from the entrance of the sewage and refuse of Peoria, into the river above this point.

6082 Table of averages for cross section of the Mississippi at the Chain of Rocks.

6084 This table contains the results of the bacterial counts made upon samples of water taken from the Mississippi river at the Chain of Rocks. The averages are arranged in their proper relation, namely, the Illinois shore, mid-stream, intake tower and Missouri shore, the count for the Missouri river being contained in the right hand column. These figures show that during the period covered by this investigation the number of bacteria in the water of the Mississippi river at this point was much lower on the Illinois shore than on the Missouri shore. It shows, moreover, that the water of the intake tower during this period partook of the character bacterially of the water of the Missouri river and of the Mississippi river on the Missouri shore. In other words, during these three months of 1901, judging from the bacterial content of the Missouri river and of the Mississippi river at this point, little, if any, water from the Illionis river entered the intake tower of the St. Louis waterworks. It is evident also from the bacterial count, that if any water from the Illinois shore did pass into the water intake, it improved the con-

dition of this water so far as reducing the number of bacteria per cubic centimeter was concerned.

I have photographs illustrating the different cross sections of the Mississippi river at this point, which are reproduced as plate No. 1, facing page 6084.

6085 Witness gives the following explanation of the photograph introduced in evidence:

To this card has been affixed five photographs of agar plates showing the number of colonies in .01 cubic centimeter, developing in different water samples collected from the Mississippi river in cross section at the Chain of Rocks, and also from the Missouri river at Fort Bellefontaine on October 28, 1901.

This is designated plate 1. These photographs show that the number of colonies appearing in the Mississippi river at the Chain of Rocks was at this date very much lower than the number in the Mississippi river at the intake tower and the Missouri shore, and also in the Missouri river.

These photographs are thoroughly representative of the results obtained at the Chain of Rocks throughout this period, October, November and December, 1901, and show clearly that the mingling of the water from the Illinois shore of the Mississippi river with the water of the Missouri river would tend to diminish the number of bacteria per cubic centimeter in the latter water.

It is also evident from these photographs that the water entering the intake tower at the Chain of Rocks, was much more largely composed of Missouri river water than of Illinois river water.

I also have photographs of other samples taken at the cross section of the Mississippi, marked No. 2, and reproduced facing page 6086.

6087 The photographs on plate 2 are the photographs of agar plates made from samples of water collected on November 20, 1901. They show the number of colonies in .01 of a cubic centimeter, developing in different water samples taken at cross section of Chain of Rocks in the Mississippi river and also from

the Missouri river at Fort Bellefontaine. They show a substantially similar condition to that obtained on October 28, 1901, as shown in plate 1. The water from the Illinois river is much freer from colonies than the water from the Missouri river, from the Mississippi river at the intake tower and from the Missouri shore.

Plate 2 shows again the close similarity between the water from the Missouri river and that taken from the Mississippi river at the intake tower and shows that in the mixing of the water from the Mississippi river along the Illinois shore, that the water from the Missouri river would diminish the number of bacteria per cubic centimeter.

Photograph or plate No. 3 reproduced facing page 6088.
6089 Plate 3 shows five photographs of agar plates made from samples of water collected from the Mississippi river at Chain of Rocks on November 13, 1901. They show the number of colonies in .01 cubic centimeter of water, developing in different samples taken in cross section at the Chain of Rocks, and also from the Missouri river at Bellefontaine.

A similar condition to that shown in plates 1 and 2 is also apparent in these photographs, namely, that the water in the Mississippi river on the Illinois shore contains fewer bacteria per cubic centimeter than the water in the Missouri river or the water at the intake tower, Missouri shore. The general similarity of the photographs of samples of water from the intake tower, the Missouri river, from the Missouri shore, the Missouri river and from the Missouri river itself shows that the water entering the intake tower at this date was in a great part, if not wholly, derived from the Missouri river. These photographs show also that in case any water from the Illinois shore of the Mississippi river intermingled with the water of the Missouri river at this date it would decrease the number of colonies developing per cubic centimeter as shown in the table of averages for this cross section at the Chain of Rocks during the period of 1901, which has just been introduced in evidence. These photographs are thoroughly representative of the conditions obtaining

in the Mississippi river during this period. The agar plates showing this condition have been selected for reproduction because of this representative character.

(Motion by Mr. Jeffries to strike out photographic plates just introduced in evidence.)

6093 I made some determinations for colon bacillus in 1901. These determinations were made from samples taken in 1901.

In 1901 from the Illinois river at Averyville and Pekin; from the Illinois river above Grafton, and the Mississippi river above Grafton, from the Missouri river at Bellefontaine and from a cross section in the Mississippi river at the Chain of Rocks. At four places, the Illinois shore, mid stream, intake tower an Missouri shore.

Q. What purpose did you have in view to be subserved in making determinations for the bacillus coli communis?

A. The relative abundance of the colon bacillus in water I consider as affording the most satisfactory indication of the sanitary quality of such water. In my opinion this is the judgment of most sanitary experts at the present time. In a paper entitled "The Significance of Bacteriological methods in Sanitary Water Analyses," published from the Biological Laboratories of the aMssachusetts Institute of Technology by C. E. A. Winslow and C. P. Nibecker, and printed in the Technology Quarterly, Volume 16, number 3, September, 1903, appears the following statement:

6094 "Colon bacilli are either wanting in good waters or are so rare as not to be found in the examination of samples of one cubic centimeter; they are found in a majority of one cubic centimeters of water so polluted as to be dangerous for drinking; between these two extremes their numbers vary with the amount of pollution. Klein and Houston in England, Jordan and Winslow and Hunnewell in America, and very recently Petruschky and Pusch in Germany have exhaustively studied the distribution of the colon bacillus with uniform results, and that the absence of this organism demonstrates the harmlessness

of a water as far as bacteriology can prove it, no one would probably hesitate to acknowledge; and that when present its numbers form a trustworthy measure of its sanitary condition, the observers above quoted have proved beyond reasonable cavil."

This statement represents my own judgment in the matter as well as what is the prevailing opinion among sanitary experts generally and it is for this reason that in my studies into bacteriological conditions existing in the waters above mentioned, I have paid particular attention to the presence and relative abundance of the colon bacillus.

I employed a method known as the Dextrose Fermentation Tube Method. Exhaustive comparative tests were made with the dextrose fermentation tube method, with the neutral red method, with the carbol broth method and other methods sometimes used in making this test with the result that the dextrose fermentation tube method proved the most reliable.

The method consistent in inoculating measured quantities of the water to be tested in fermentation tubes containing ordinary nutrient broth with an addition of one per cent dextrose.

The interpretations adopted for the changes so produced were as follows:

States method employed in the determination of the colon bacillus in this examination made in 1901.

6095 Positive reactions, that is those indicating presence of B. coli were regarded as those tubes showing the gas production of over twenty per cent of the tube length; the tubes yielding on absorption with sodium hydroxide a gaseous residue appreciably in excess of the carbon dioxide observed. Negative reactions were those showing.

(a) No gas production or

(b) Gas production less than ten per cent of the tube length.

The doubtful class were made to include:

(a) Those tubes yielding only ten to twenty per cent of gas, and

(b) Those yielding more than twenty per cent before that appreciable excess of carbon dioxide.

A series of fermentation tubes was examined in detail to determine the limits of accuracy of this method, with the result that out of sixty-three tubes examined in thirty-nine cases where the interpretation was positive typical bacillus coli communis was isolated from the tube and identified in all its biological characteristics.

In seven cases where the presumptive test yielded a positive result the bacillus coli was not isolated. This may have been and in my opinion was because the colon bacillus after producing its characteristic fermentation changes was subsequently overgrown by other forms such as the sewage streptococcus.

In nine cases where the interpretation was doubtful the colon bacillus was not isolated.

In four cases where the interpretation was doubtful typical bacillus coli was isolated.

In four cases where the interpretation was negative the bacillus coli was not isolated.

It may be added that these last named cases were those showing less than ten per cent of gas in which gas forming organisms not B. coli were isolated. In addition some twenty tubes were examined which showed growth in the closed arm but yielded no gas producing organisms of any kind.

These results, in my opinion, show conclusively that where a large number of water samples are treated the error due to relying on the presumptive test alone is not unduly large.

The specific application of this method to the problem of self purification of streams depend upon ascertaining in each case the dilution at which the tests give uniformly positive and that at which it gives uniformly negative results. This method which rests upon the determination of the relative abundance of

the colon bacillus is an extremely delicate test for recent sewage pollution.

6096 Winslow and Nibecker in the paper just refefred to, on the significance of bacteriological methods in sanitary water analyses state, on page 237, "In the second place the bacteriological methods are far more delicate than in the others. Klein showed experiment with dilutions of sewage that the colon test was from ten to one hundred times as successful as the methods of chemical analyses."

"Studies of self-purification of streams have confirmed these conclusions on a practical scale. Thus, "in the Sudbury river it was found that while the chemical evidence of pollution persisted for six miles beyond the point of entrance the bacteria introduced could be detected for four miles further."

This latter statement refers to the study of self purification in the Sudbury river in Massachusetts carried out by A. G. Woodman, C. E. A. Winslow and P. Hansen, and published in the Technology Quarterly, Volume 15, 1902, page 105.

I prepared tables of the results of the analyses which I made in regard to the colon bacillus. Table designated "Illinois river, Averyville, presence of bacteria of the colon group," includes a record of determinations made on daily samples collected between October 19th and December 30th, 1901, reproduced on page 6097.

6099 The table shows that during this period the colon bacillus was never found in .001 cc. That it was but rarely found in .01 cc. (4 positive out of 72 determinations.) That it was found 49 times out of 114 determinations in .1 cc. and 39 times out of 54 determinations in .1 cc. Table headed "Illinois River —Pekin, Presence of bacteria of the colon group," reproduced on page 6099, includes the colon determinations made daily between October 19 and December 30, 1901. Shows that out of 25 determinations made with .001 cc. of river water taken from the Illinois river at Pekin, the colon bacillus was found in 28 per cent of the samples examined. In .001 cc. in 21 per cent; in

.1 cc. 78 per cent and in all 100 per cent of the 1. cc. samples.

6101 The table number 3, entitled "Illinois river, Grafton, Presence of bacteria of the colon group," includes a record of colon determinations made daily between October 10th and December 24th, 1901, and is reported on page 6101.

6104 This table shows that the colon bacillus was present in 7 per cent of the .001 cc. samples.

In 5 per cent of the .01 cc. samples.

In 13 per cent of the .1 cc. samples, and

in 30 per cent of the 1. cc. samples.

Table number 4, headed "Mississippi River, Grafton, presence of Bacteria of the Colon Group," includes a record of colon determinations made daily from the water of the Mississippi river above Grafton between October 10 and December 24, 1901, and is reproduced on page 6104.

6106 This shows that the colon bacillus was present in five per cent of the .001 cc. samples; in 24 per cent .1 cc. samples; in 38 per cent of the 1. cc. samples. Table number 5, headed "Missouri River, Bellefontaine, Presence of Bacteria of the Colon Group," contains the result of daily determinations made upon samples of Missouri river water between October 23 and December 17, 1901, and is reproduced on page 6106.

6108 This shows that the colon bacillus was present; in 19 per cent of the .001 cc. samples, in 50 per cent of the .01 cc. samples, in 79 per cent of the 1. cc. samples. Tables No. 6, 7, 8 and 9 contain records of the daily colon determinations made upon the water of the Mississippi river at the Chain of Rocks, in cross sections, as previously described in my testimony, viz: At a point near the Missouri shore, at the intake tower, in mid-stream, and at a point midway between the Illinois shore and mid-stream, made between October 22 and December 14, 1901, and reproduced on page 6109.

6117 These tables show that on the Missouri shore the colon bacillus was present in 13 per cent of the .01 cc. sample.

In 41 per cent of the .1 cc. sample, and

88 per cent of the 1. cc. sample.

At the intake tower the colon bacillus was present in 20 per cent of the .01 cc. sample, and in

57 per cent of the .1 cc. sample, and

84 per cent of the 1. cc. sample.

In the samples taken from mid-stream the colon bacillus was present in 6 per cent of the .01 cc. sample,

In 22 per cent of the .1 cc. sample,

81 per cent of the 1. cc. sample.

In the water of the Mississippi river at the Illinois shore the colon bacillus was present in

5 per cent of the .01 cc. samples,

10 per cent of the .1 cc. samples,

60 per cent of the 1. cc. samples.

Q. Did you prepare a table of summaries based upon the coli tables which you have already introduced in evidence?

A. Yes, sir, I have them here.

6118 Table A of summaries read in evidence.

6119 This table shows the presence of bacteria of the colon group in the water collected from the stations just set forth. This table shows the total number of days on which water was examined during this period and the total number of days on which bacilluscoli was found.

6120 Table B read in evidence.

6121 Table B shows that the total number of determinations made from samples of water collected from the already specified points in the Illinois, Missouri and Mississippi rivers, together with the number of positive results and the percentage of positive results.

In my opinion the fate of the colon bacillus in running water furnishes a very satisfactory indication as to the degree and rate of self-purification in such water.

The fact that the colon bacillus is present in but 43 per cent of the .1 cc. examinations from the Illinois river at Averyville while it is present in 100 per cent of the .1 cc. samples taken from the Illinois river at Pekin and in only 13 per cent of the

.1 cc. sample taken from the Illinois river at Grafton shows not only the extreme delicacy of this test for sewage pollution but shows a very considerable improvement in the sanitary quality of the water occurs between Pekin and Grafton, notwithstanding the large amount of pollution at Pekin. Comparing the condition of the water in the Mississippi river above Grafton with that in the Illinois river above Grafton as evidenced by the colon content of these two waters, it appears that the colon bacillus was present in 5 per cent of the determinations made of .01 cc. of water from these two places.

It may be mentioned that 117 determinations were made of the Illinois river water above Grafton and 115 of the Mississippi river water above Grafton during this period, so that the substantial agreement in percentage shown in the sanitary character of these waters during this period has a satisfactory statistical basis.

Comparing the examinations made of .1 cc. of water during the same period it is shown that 24 per cent of the samples from the Mississippi river yielded positive results while 13 per cent of those from the Illinois river above Grafton yielded positive results.

In 1. cc. of water from those two stations 38 per cent of the samples from the Mississippi river and 30 per cent of those from the Illinois river gave positive results.

6122 In other words, so far as any conclusion as to the sanitary character of these waters can be drawn from the colon determinations—and I have already indicated that in my opinion and in that of sanitary experts generally, the colon test is the most delicate and satisfactory clue that we have to the sanitary condition of the water—the water of the Mississippi river above Grafton during this period was, if anything, of a less wholesome character than the water of the Illinois river above Grafton.

Comparing further the colon content of the Missouri river water above Bellefontaine during this period it is shown that 19 per cent of the .01 cc. samples were positive as compared with

5 per cent in the Illinois river at Grafton, and that 50 per cent of the .1 cc. samples were positive as compared with 13 per cent in the Illinois river at Grafton and that 79 per cent of the 1. cc. samples were positive as compared with 30 per cent in the Illinois river above Grafton.

Comparing the per centages of positive results obtained in the examination of 1. cc. of water in cross section at Chain of Rocks it appears that there was a smaller percentage of colon bacteria in the Mississippi river on the Illinois shore and in mid stream than at the intake tower and on the Missouri shore. This confirms the difference already noted between the colon content of the Illinois river and the Mississippi river at Grafton and that of the Missouri river at Bellefontaine. The higher colon content of the Missouri river betrayed itself in the larger number of colon bacilli found in the Mississippi river at the intake tower and near the Missouri shore at the Chain of Rocks.

The sanitary significance which I attach to these findings is based on what I have been able to learn by my own observation and experiments regarding the significance and relative abundance of the colon bacillus in waters of various kinds as well as that derived from an examination of the available literature on the subject and the opinions of various sanitary experts already referred to in my testimony. It may be summed up by the statement that the water from the Missouri river during this period was distinctly more dangerous and unwholesome than the water of either the Illinois or the Mississippi river at

Grafton, and further that the difference between the Illi-
6123 nois river above its mouth and the Mississippi river above

Grafton while not great shows that on the whole the Illinois river was in a less highly polluted condition than the Mississippi.

Those examinations were made in pursuance of an agreement mutually entered into between the representatives of the complainant and the defendant. Plate IV is a photograph of fermentation tubes, showing differences in amount of gas production in said tubes, in samples of water taken from the Missis-

sippi river at the Chain of Rocks, and Missouri river at Fort Bellefontaine. Reproduced facing page 6126.

6127 Witness explains what is shown by the photographs.

6128 These four photographs illustrate entirely typical conditions in the water of the Mississippi river at the Chain of Rocks and show that as a rule the water from the Missouri river and from the Missouri shore and intake tower of the Mississippi river and the Chain of Rocks contains the colon bacillus in larger numbers than the water of the Mississippi river along the Illinois shore. Plate V reproduced on page 6130.

6131 Plate 5 shows photographs of a series of 30 fermentation tubes prepared from samples of water collected from the Mississippi river on November 23, 1901, in cross section at the Chain of Rocks and from the Missouri river at Bellefontaine. On the left of the photograph are the samples taken from the Mississippi river, Illinois shore; only one of these, viz: that in which 1. cc. of water was inoculated shows gas production. The same is true of samples of water taken from the Mississippi river in the channel, although more gas was produced in this case.

The sample of water taken from the intake tower shows gas production, not only in the 1. cc. tube but in the .1 cc. tube, and in one of the .01 cc. tubes.

An entirely exact correspondence is shown by sample No. 200 taken from the Mississippi river at the Missiuri shore. 4 tubes showed gas production in this case also.

The Missouri river, No. 201, shows a very similar condition, except that no gas was produced in either of the .01 cc. tubes.

This close correspondence between the colon content of the Missouri river and that of the Mississippi river along the Missouri shore and at the intake tower points in my opinion unmistakably to the conclusions that the sanitary character of these waters was very similar, and the water flowing past the intake tower at the time at which these samples were collected was derived in a large part from the Missouri river rather than from the Mississippi or Illinois.

The close agreement between the samplees from the Illinois shore and the channel shows the essential uniformity of the body of water from those two sources and shows, furthermore, that from the sanitary point of view the water in this part of the river was less unwholesome, less highly charged with objectionable bacteria than the water from the Missouri river or than the water in the Mississippi river at the intake tower.

Q. What do the photographs show, professor, as to the mixing of the waters at this point of the three rivers?

A. They show that as far as the bacterial content is concerned the water flowing along the Missouri shore and by the intake tower was derived in large part if not wholly from the Missouri river while the water derived from the Illinois river clings to the Illinois shore and mixes little, if any, with the water of the Missouri.

6132 The character of these waters during this period as shown by the colon examinations and as set forth in the tables and illustrated by the photographs is quite different. The colon content of the Missouri river is markedly higher than that of either the Illinois or the Mississippi river at Grafton, and from this I infer that during this period the Missouri river was more highly charged with dangerous bacteria and was distinctly less safe than the waters of the Illinois river.

Under these conditions the effect of any mixture of the Illinois river water with the Missouri river water at the intake tower of the St. Louis waterworks would therefore tend to diminish the colon content of the water at that point, thereby rendering it less dangerous for the human use. Such mixing of the Illinois and Missouri waters as took place would hence improve the conditions existing during this period in the Mississippi river at the intake tower.

Throughout this period, in the later part of 1901, the water was low in the three rivers, the Illinois, the Mississippi and the Missouri.

MR. TODD: Professor, Mr. Allen Hazen, on page 4530 of the record, was asked this question " when the mixing begins

at the mouth of the Illinois river, by the time it gets to the mouth of the Missouri river, is that mixing complete" and he answered "I do not think it is absolutely complete. It is approximately so; more so at low water than at high water." What do your bacterial analyses show as to whether there is more mixing of these waters at low water than at high water.

6133 I may state in reply that in my opinion the total number of bacteria in the water at the intake tower and near the Missouri shore at the Chain of Rocks as well as the number of colon bacteria in the water at these points shows conclusively that during this period of low water, the water collected at these two stations was almost wholly if not altogether Missouri river water and was mixed a little, if any, with the water from the Illinois. If it be true, therefore, that mixing is more complete at low water than at high water it will certainly follow that the amount of Illinois river water present in the Mississippi at these two points at high water stages must be exceedingly small.

I made an extended examination of species of bacteria taken from the river water at the three stations already described. That includes six points. I made a table of results, which said table is marked table No. 2 and is reproduced on page 6134.

6135 This detailed study of species shows that on the whole those forms regarded by bacteriologists as characteristic of sewage pollution are found more abundantly in the water of the Illinois river at Pekin than elsewhere. The Streptococcus forms which are believed by some to be specially characteristic of recent sewage pollution were found in four cases only, viz: two in the Illinois river at Pekin and two in the Mississippi river near the Missouri shore. The results as a whole confirm the deductions drawn from the study of the colon tables.

(Referring to the question of the practice in this country as to the number and time of determinations of river water, in order to determine the sanitary quality of same, witness refers to

works of investigators in this country wherein examinations were made daily and weekly for a certain period of the year.

Witness then states:)

6136 In European countries, so far as I know, no extended examinations of river water, based on daily and weekly analyses, have been made, which cover so long a period of time as those that have been made in this case.

It is, therefore, my opinion that the usual practice of those experts having to do with the examination of river waters in this country is based on the belief that an adequate opinion as to the character of the water can be formed by examinations made at intervals as frequent and during periods as long as those indicated in the instances just cited.

6137 The examinations which I have made in behalf of the Sanitary District of Chicago cover two periods, the first, one of weekly examinations extending from about the first of May, 1899, to the first of July, 1900. During this period the regular weekly examinations were supplemented by daily and in some instances hourly examinations of the river waters at several points. The second period includes daily examinations made between about the first of November, 1901, to about the first of January, 1902. In all, the examinations that I have made cover a period of one year and five months. It is decidedly my opinion that it is possible to pass a competent judgment upon the waters of the Illinois, Mississippi and Missopri rivers on the basis of the analyses I have submitted in my testimony. The analytical data, chemical and bacterial, that I have secured by these weekly, daily and hourly determinations, extend over a sufficient interval of time and include sufficiently varying conditions to permit of a satisfactory judgment being rendered as to the general character of the waters dealt with. The separate analyses number many thousands and the results embody the experience gleaned from a study of high water and low water conditions, of summer and winter temperature, and of varying climatic and meteoroligical factors. It is my judgment that taking into consideration the analyses made concurrently

by Professors Palmer, Long, Zeit, Gehrmann and Burrill, no such extensive and exhaustive study of river water, in connection with the problem of self purification of streams, has ever been made anywhere in the world as that carried out during this period. From my survey of the Missouri and Illinois rivers, as evidenced by the various analyses heretofore testified to in this case, prior to the 17th of January, 1900, the condition of the Missouri river as compared with that of the Illinois above Grafton was less satisfactory from a sanitary point of view and was distinctly inferior to the Illinois river at Averyville.

6138 The relative character of the two rivers was not materially different from the 17th of January, 1900, to the first of July, 1900. That is to say, the Missouri river water was more objectionable from a sanitary standpoint than the water of the Illinois river at its mouth or at Averyville.

During the period October-December, 1901, when daily examinations were made and a large number of results obtained, the sanitary quality of the Missouri river water was, in my opinion, distinctly inferior to the Illinois river water at its mouth and at Averyville, as shown especially by the colon determinations.

Taking into consideration all the analytical data that I have obtained throughout the seventeen months covered by the investigations, I conclude that one of the most remarkable facts, if not the most remarkable, is the entire concurrence of the results derived from the chemical and the various bacterial determinations. The amount and rate of nitrification in the water of the Illinois river at various points along its course, as shown by the tables of chemical analyses, are in line with what the experience of water analysts has shown to accompany a real purification. The large amount of organic matter present in the upper stretches of the Illinois river is oxidized during its passage down stream, and before Averyville is reached the nitrification of this organic matter has progressed practically to completion.

On the bacterial side, the evidence is wholly confirmatory

of this improvement in the quality of the Illinois river water. The enormous number of bacteria poured into the Illinois river in its upper stretches, as shown by the number of bacteria
6139 present in the Illinois river at Lockport and Joliet, is greatly diminished in a flow of less than one hundred miles. Under certain conditions even, and at certain periods of the year, the Illinois river becomes nearly free from the great mass of sewage bacteria with which it was originally laden in as short a distance as 24 miles, as evidenced by the observations between Morris and Ottawa, already introduced. Both at Averyville and above Grafton the bacterial composition of the Illinois river water is about the same as that of tributary streams and as that of the Mississippi river just above Grafton. The colon contents of the Illinois river is in my opinion, especially significant from a sanitary point of view, and affords evidence in entire harmony with the conclusions derived from the chemical examinations and from the number of bacteria of all kinds shown to be present in these waters. The colon bacteria which are found in great abundance in the waters of the drainage canal and in the upper stretches of the river practically disappear before Averyville is reached.

It is clear from the data that I have presented that the water of the Illinois river undergoes a real and very considerable purification. The colon bacteria which are shown to be present in large numbers in Chicago sewage disappear almost completely in less than 150 miles flow. At the mouth of the Illinois river, despite the enormous initial pollution and the very large secondary pollution at Peoria, the number of colon bacteria is certainly no greater than the number in the Mississippi river at this point, and not as large as the number in the Missouri river at Bellefontaine. Since all investigators are agreed that the colon bacillus is more hardy than its relative, the typhoid bacillus, and can live in water for a longer time there is every reason for supposing that the latter microbe dies out with at least the same rapidity. If it be true, as I firmly believe to be the case, that the fate of the colon bacillus in

running water furnishes the most satisfactory indication we can secure at present of the continuance of vitality of the typhoid bacillus, there can be no hasitation as to the conclusion to be drawn from this investigation. Since this biological relative of the typhoid bacillus perishes speedily and in large numbers in the course of the Illinois river, it is my opinion that the typhoid bacillus itself cannot long survive exposure to the same conditions.

The study of bacteria has been my main occupation for some 15 years. (Witness states what bacteria are, how they are classified and distinguished, how they are distributed, the characteristics of bacteria peculiar to waters and distinguishes between the so-called saphrophytes and parasites and between non-pathogenic and pathogenic bacteria.

6143 States the characteristics and life history of the bacillus prodigiosus.) The bacillus prodigiosus has been found in the waters of rivers and in other bodies of water in various parts of the world. On November 6, 1899, I isolated from the water of the Illinois river collected at Morris an organism which in all the characters I have described resembles exactly the bacillus prodigiosus. I have here a sheet of species description in which the biological characteristics of three cultures of bacillus prodigiosus obtained respectively from the University of Michigan Bacteriological Laboratory, from

6144 Yale University, and from the Ontario Board of Health, are tabulated. This shows that the characteristics of these three organisms, were similar. The organism isolated from the water of the Illinois river just above Morris on November 6, 1899, possesses all the characteristics manifested by these three specimens of bacillus prodigiosus and it is in my opinion a member of that group.

In addition to this form that I have identified as bacillus prodigiosus I found on several occasions organisms which resembled the bacillus prodigiosus very closely, and might on superficial examination be mistaken for it.

(Witness states in what respects these organisms differ

from the true bacillus prodigiosus type. Witness made a diagram showing species description of the prodigiosus from the University of Michigan, Yale University, Ontario Board of Health and the one which he separated from the Illinois river at Morris on November 6, 1899, also that found in the Mississippi river near the Missouri shore near the Chain of Rocks, November 16, 1901, which chart or diagram discloses the fact that the supposed bacillus prodigiosus found in the Mississippi river differs in three very important respects from the true bacillus prodigiosus type.

6148 On several occasions we have isolated from the water of the Illinois and Mississippi rivers organisms which in many particulars, especially in regard to pigment production, resemble very closely the typical bacillus prodigiosus. These organisms differ oftentimes in very slight degree from the true prodigiosus type. The differences consist, for the most part, in variations in their actions upon milk, gelatin, casein and blood serum and in their action upon the different sugars. Any examination of these organisms, other than a searching and detailed one, might lead to their being mistaken for the true prodigiosus type.

I read the testimony of Dr. Ravold wherein he detailed the result of what is known as his prodigiosus experiment. That experiment seems to me to constitute a demonstration of the power of self purification in streams, from the fact that along the upper collecting stations in the Illinois river this organism was not recovered, although frequent examinations were

6149 made of the water at these points and although, according to the testimony, prodigiosus numbers of this organism were introduced into the water of the drainage canal.

As regards the finding of a few individuals in the water of the Mississippi river, assumed to be of the same variety as that introduced, I can only say that the identification does not appear from the records to be altogether complete. And, furthermore, assuming that the organisms recovered from the Mississippi river were actually those introduced in the drainage canal,

the appearance of so small a number would not in itself be significant. This is true especially since organisms belonging to this prodigiosus group, as has been shown, are sometimes found in the water of these rivers and are saprophytic forms which are evidently rather easily habituated to acquatic life.

(Witness is asked a hypothetical question assuming the deposit of 107 barrels of bacillus prodigiosus culture into the canal, the subsequent examination of the waters for its discovery and the finding of one bacillus at certain points at a later period, as heretofore testified.)

6150 In my opinion this experiment sheds a certain amount of light on the probable longevity of a typhoid bacillus under the conditions as stated. This is true for the reason that the relatively insignificant findings of bacillus prodigiosus, assuming identification to be correct, indicate that this organism, while in a fairly hardy saprophytic form, does not live long in the river water, and that the typhoid bacillus, which is beyond doubt a more highly specialized parasitic form than bacillus prodigiosus, would not survive as long as the latter. The

6151 experiment, in my judgment, affords strong confirmation of the evidence already derived from a study of the death rate among colon bacilli in the water of the Illinois river. Since bacillus prodigiosus dies off so speedily and in such large numbers, the typhoid bacillus would be less likely to survive exposure to these same conditions.

(Witness gives characteristics and pathological significance of cholera germ and tetanus germ.) I know of no instance where a case of tetanus has been traced to water borne infection. The germ is common in street dust, finding its way there probably from the droppings of horses in which it is usually present in considerable abundance. (Gives characteristics and pathological significance of anthrax germ.)

6153 There are a few cases on record where the refuse from tanneries has been washed into stream and deposited on fields; and cattle grazing on these fields have been known to became infected. There are also a few cases where the water of a

well has become infected in this way and has caused disease among cattle. So far as man is concerned, anthrax is not, properly speaking, a water borne disease, since infection from this source, if it has ever occurred, is extremely rare. (Gives characteristics and pathological significance of the bacillus enteritidis sporogenes.) When this germ enters the human system through drinking water it will not produce disease so far as known. The evidence indicates quite the reverse. (Witness gives characteristics and pathological significance of dysentery bacillus and typhoid germ.)

6155 The typhoid germ is related to the colon bacillus in being a member of this large colon typhoid group. It differs from the colon in being less vigorous. I have already shown that as regards longevity in water, resistance to freezing, to drying and other adverse conditions of life, the colon bacillus is a more hardy organism than the typhoid bacillus.

6156 There are cases on record where even years after an attack of typhoid fever, the typhoid bacillus has been found in the bone marrow and other situations in the body of human beings. Outside of the human body, on the other hand, the life of the typhoid bacillus is comparatively brief. There is no evidence that it can remain alive in the water for more than a few days. It may remain alive in accumulations of dejecta in outhouses and privies for a much longer time and in the soil also it may retain its vitality for a considerable period. Although the evidence which connects polluted water supplies with outbreaks of typhoid fever is entirely convincing both in character and mass, there have been relatively few instances in

6157 which bacteriologists have succeeded in isolating a specific typhoid bacillus from suspected waters. (Witness then gives names of investigators who claim to have found typhoid bacillus in water.)

6158 There are therefore perhaps six cases where undoubtedly typhoid bacilli have been isolated from ordinary drinking water.

The meagreness of the findings despite the thousands of

examinations that have been made by skilled bacteriologists in every part of the world is in my opinion explained chiefly by the relative short duration of the life of the typhoid bacillus in water. The period elapsing between the moment of infection and the initiation of bacterial investigation is usually at least two or three weeks, owing chiefly to the time occupied in incubation and in the insidious development and perhaps tardy recognition of the disease. Sometime is also consumed by the preliminaries necessary for the setting on foot of competent investigation. It is apparently only under exceptional conditions, such for instance as obtained in the case reported by Kubler and Neufeld, that the life of the bacillus can be extend throughout any considerable period. The history of most outbreaks of typhoid fever shows that the bacilli have disappeared from the water by the time search is inaugurated and it is for this reason that a negative finding is the usual result of bacterial examination.

6159 (Witness gives results of experiments made upon the life of the typhoid bacillus in sterilized waters kept in glass bottles in a laboratory.) In sterilized Lake Michigan water the bacillus does not multiply but may, under certain conditions, maintain its vitality for upwards of 93 days. The colon bacillus, under similar conditions under goes rapid multiplication and may remain alive for upwards of 262 days. I know of no evidence that the typhoid bacillus multiplies and increases in nature. On the contrary, from an examination of literature, the evidence appears to me overwhelming that typhoid bacilli as soon as discharged from the human body undergo a constant diminution in number. In my opinion the conditions of laboratory experiments are decidedly more favorable to the longevity of the typhoid bacillus than the conditions which obtain in nature. (Witness gives his reasons.)

6160 From what I know of the chemical composition and bacterial content of the waters of the Illinois river at various points along its source, it is my opinion that the life of the typhoid bacillus introduced into the Illinois river at the upper end

of the drainage canal would not be more than three or four days. I think the germ will live longer in pure water than in polluted water. It is well known from the experiments of many observers that it lives longer in sterilized water than in unsterilized. I attribute this to the saphophytic microbes which inhabit polluted and unsterilized waters. (Witness gives reasons for above statement.)

6161 Am acquainted with the Chicago river, the drainage canal, the Des Plaines river, the Illinois river and the Mississippi river from Grafton to St. Louis and the Missouri river as it empties into the Mississippi. Witness states opportunities for becoming acquainted with the above named rivers and the tributaries of the Illinois, consisting of personal visits and inspection of the same between the years 1899 and 1903.

6163 (Witness describes the physical conditions of the Illinois river and its tributaries.)

From the point where the drainage canal empties into the Des Plaines river at Lockport, the fall is quite rapid to a point somewhere below Morris. The lower portion of the Illinois river, especially that part of the river from La Salle to the mouth of the Illinois at Grafton is very sluggish and consists of a series of pools in which the current is very slow and in which opportunities for sedimentation abound. In the lower reaches of the river the current is so slight as to be hardly noticeable. At intervals in the course of the river, dams are located; one at Marseilles, between Morris and Ottawa, one at Henry: between La Salle and Averyville, one at Copperas creek, some 58 miles below Peoria and two others between this point and Grafton at La Grange and Kampsville. These dams accentuate the tendency of the river to form pools and back waters. At Joliet and above Peoria there are wide expansions of the river known respectively as Lake Joliet and Lake Peoria. In these expanded reaches the current is very slight and the body of water as a whole is almost entirely quiescent. At many points along the course of the river, especially below La Salle,

the banks of the river are low and an increase in the height of water in the river causes an overflow of the surrounding country flooding the meadows and low lands adjacent to the river bank. In the lower 225 miles of the Illinois river there is a fall of only about 30 feet and the extremely sluggish current thus produced affords nearly ideal conditions for sedimentation. During the flood stages the valley of the Illinois river becomes virtually a great lake into which flood waters from the upper portion of the valley and tributaries are precipitated, and from the lower end of which they pass out in diminished and equalized volume.

If it were true that any of the infecting and polluting matters from Chicago reached as far down even as Lake Peoria, the conditions existing there and farther down the Illinois
6164 river would be such as to bring about a further diminution in the amount of the substances. Under the circumstances of semi-stagnation already enumerated, the settling out of food particles, the entanglement of the bacteria in these, and possibly the slow sinking of the bacteria themselves would all have full effect and would work to diminish the number of suspended bacteria.

6165 I regard the conditions of semi-stagnation prevailing in the Illinois river at most points along its course as an important factor in influencing the fate of polluting and infectious matters added to the water of this stream and to the various tributaries. The exceedingly low gradient in the river which has been already referred to and which is further accentuated by dams at various points, retards the progress of suspended matters down stream and affords highly favorable conditions for purification. This is most marked during period of low water but at high water the flooding of the low lands and the meadows along the banks of the river also affords opportunity for sedimentation and the retarding influences are still active. It is my opinion that the conditions prevailing in the Illinois river during summer and winter, during low water and high water, are much more favorable to the self purification of the

stream than conditions that exist in a stream flowing over a bed with a steep gradient where any infectious elements introduced might be hurried down without opportunities for sedimentation or for loss of vitality. The considerable time that must be consumed by a given mass of water flowing along the Illinois river affords opportunity for the death and destruction of such infectious and polluting matters as may be introduced into this river, either directly or from the tributaries.

6166 Sedimentation of bacteria occurs more quickly in water containing a considerable amount of suspended mater than it does in water which is relatively clear. As to the effect of the dilution of the sewage of Chicago with Lake Michigan water, there is at times a considerable amount of suspended matter in the water of Lake Michigan near the mouth of the Chicago river, but on the whole, the water of Lake Michigan is not a turbid water. In that portion of the Illinois river, however, where most sedimentation occurs, the amount of suspended mater introduced into the water from the tributaries and entering the river directly, is, in my judgment, sufficient to affect the same degree of sedimentation that would occur if the present amount of dilution with Lake Michigan water at the extreme upper end of the river was absent. In my judgment if the sewage of Chicago is turned into the drainage canal, diluted by one million cubic feet of Lake Michigan water per minute, such a dilution as that indicated would affect the degree of sedimentation in the Des Plaines river and probably in the upper part of the Illinois near the union of the Des Plaines and the Kankakee, but in the lower part of the Illinois river, especially in that stretch from La Salle to Grafton, where sedimentation is most active, it is my opinion that such dilution as that described would not materially affect the degree of sedimentation of bacteria. From what I know of the physical conditions of the Illinois river, and

of the character of the various tributary streams, it is my opinion that there would be sufficient suspended matter in
6167 the water to bring about a mechanical dragging down of bacteria,, and, moreover, that such an increase in the body of water as might result from this dilution would result in the spreading out of water of the Illinois river over the low lands, thus affording peculiarly favorable conditions for the sedimentation of bacteria.

When polluting or infectious matters are added to a water it naturally follows that the greater the dilution of such matters the less dangerous is a given quantity of such water, such for instance as a quart or a liter. In this sense dilution with a purer water may be said to increase the purity of the stream. So far as the actual destruction of infectious elements is concerned, dilution to such an extent as usually occurs, probably has but little influence.

Danger of infection is diminished by dilution for the reason that the infected matter is spread over a large area. Considering the conditions at the mouth of the Illinois river above Grafton, I should say that the dilution of Chicago sewage with the pure water of Lake Michigan has little if any effect upon the infectious quality of such water, since whether the sewage be diluted or not, death of any typhoid bacillus originally present therein would occur, in my opinion, long before the mouth of the Illinois river was reached.

6169 Assuming that the water of Lake Michigan under the conditions stated to Prof. Sedgwick on page 3542 of the record, passes through a conduit from the Lake front of Chicago to the Mississippi river at Grafton, I would say that I do not consider that it would be a menace or danger to the inhabitants of the State of Missouri and especially to the citizens of St. Louis drinking the Mississippi river water in its raw condition. I make this answer because in my opinion the typhoid bacillus would not survive exposure to the conditions in such a closed conduit any more than in my opinion it does survive exposure to the conditions existing in the Illinois river. And further-

more, assuming that no greater mixing of such water with the waters of the Mississippi river and Missouri river occurs than is the case at present it is my judgment that a very small portion of such water would reach the intake tower of the St. Louis waterworks, pass through the settling basins and be delivered to the inhabitants of the city of St. Louis.

Assuming the conditions in the Missouri and Mississippi river to be as they are at present, it is my judgment that the water issuing from such a conduit, and experiencing the same degree of purification which now takes place in the Illinois river, would tend rather to improvement and purification of such water so far as it might mingle with it.

The physical conditions of the Illinois river are better suited for the purpose of purification than are those of the Mississippi and Missouri rivers. (Reasons stated on page 5170.)

6172 (Witness is referred to answer of Prof. Sedgwick on page 369 of his testimony wherein he states that the river pollution commissioners of Great Britain in a report published by them in 1874 state there is no river in England long enough to purify itself from any sewage admitted to it, even at its source. That stands as one of the axioms of sanitary science today. Same statement was also made on page 4398.)

6173 The River Pollution Commission's report for 1874 states: "It will be safe to infer, however, from the above results, that there is no river in the United Kingdom long enough to effect the destruction of sewage by oxidation." At the time this report was published in 1874, the knowledge of sanitarians regarding the quality of water, was based on chemical data, this being before the rise of the science of bacteriology. Practically nothing was known at that time regarding the elements in sewage that imparted to its dangerous character. It does not, by any means, follow that because complete destruction by oxidation of the organic maters contained in a sewage polluted water does not occur within a specified distance, that the real purifica-

tion of the sewage, that is to say, its freedom from dangerous bacteria may not be accomplished within that distance.

6175 I have examined the report of the Rivers Pollution Commission of 1874 with some care and have failed to discover in it any statement that no river in the United Kingdom is long enough to purify itself of any sewage introduced into it at its source. As to the effect of the sewage of Chicago discharged into the drainage canal, upon the waters of the Mississippi river as the same passes along the shore of the State of Missouri, I would say that a large amount of harmless inorganic

6176 chlorine in the water of the Illinois river at its mouth is derived chiefly from the sewage of Chicago and Peoria. So far as the water of the Illinois mingles with that of the Mississippi along the Missouri shore, so far is the chlorine content of the water heightened. In respect to the other constituents of the Illinois river water, the sewage introduced at Chicago influences the total amount of nitrogen compounds in said water. This is especially true of the nitrates, which are usuelly high at Grafton. In respect to the bacterial content of the water, the mixing of the Illinois with the Mississippi does not in my opinion introduce into the mixture any significant number of bacteria derived from the sewers of Chicago. It is my opinion that practically all the bacteria introduced into the drainage canal from the Chicago sewers perish long before the mouth of the Illinois is reached.

6177 I conclude that the sewage from Chicago, introduced into the drainage canal, has no injurious effect upon the waters of the Mississippi as the same passes along the shore of the State of Missouri.

I am unable to differentiate clearly between infectious matter and pollution dangerous to public health in this connection, since polluting matters dangerous to the public health are, so far as I am aware, those able to communicate infection. I, accordingly, would answer this question in the same way as I have answered the preceding, namely, that in my opinion no infectious matter coming from the sewers of Chicago by way

of the drainage canal reaches as far down the Illinois river as the city of Grafton.

It is my opinion that no pollution dangerous to public health entering the drainage canal from the sewers of Chicago, reaches as far down the Illinois river as Grafton. I know of no evidence bacterial or chemical that would justify the conclusion that polluted and infected matter coming from the sewers of Chicago would reach as far down the Illinois river as Grafton. On the contrary, the evidence of which I am cognizant points to a precisely opposite conclusion. In my

6178 judgment the Illinois river at its mouth does not contain infectious matter of a dangerous character, derived from the sewers of Chicago, and so could not be a factor in carrying infectious and polluting matters from the sewers of Chicago to the city of St. Louis.

6179 From my knowledge of the conditions that obtain in Chicago and the drainage canal, it is my judgment that the sewage of Chicago has no injurious or deleterious effect upon the water supply of the city of St. Louis or upon the water of the Mississippi as it passes along the shore of the State of Missouri.

6180 I base my opinion that the typhoid bacillus will not live more than three or four days under conditions as they obtain in the drainage canal, the Des Plaines river and the Illinois river, chiefly on an elaborate experiment that I have recently carried out on the life of the typhoid bacillus under natural conditions in the water of the drainage canal at Robey street and at Lockport.

This experiment was conducted under the supervision of Prof. Russell of the University of Wisconsin, Prof. Zeit of the Northwestern Medical School and myself. (Wtiness states method of conducting the experiment referred to. It is im-

portant that the testimony as to this experiment, which is reproduced on the above page, *et seq*, be read.)

6198 Table I shows results obtained by the experiment performed at Lockport. This table shows that from one to nine days plates were taken, on none of which typhoid colonies were found.

6199 Table II shows result of experiment at Lockport in waters of the Drainage canal. This table shows that no typhoid colonies were found in from one to nine days.

6201 Table III, drainage canal at Lockport. This table shows that colonies were picked off every day for seven days and no typhoid bacilli were found among this number.

6202 Table IV, drainage canal at Lockport. Colonies were picked off every day from one to ten days inclusive, without discovering any typhoid bacilli.

6203 Table V, drainage canal at Lockport.

6204 This table shows that colonies were picked off for five days, none of which proved to be typhoid.

These early experiments gave negative results throughout largely because of the number of typhoid bacilli added in these cases; but especially because in these early experiments the time allowed to elapse after inoculation before a very large number of colonies were examined was in most cases too great, as is shown by the later experiments in which a shorter interval was allowed to elapse between inoculation and examination of the material in these sacs. The experiments, for example, recorded in table IV where no examinations were made of the water of the sac until after 3 days had elapsed is a case in point.

The outcome of these early experiments convinced us that if typhoid bacilli were to be found at all in the waters of the drainage canal under these conditions it must be by ex-

aminations made within a short time after the infection of sacs had been effected.

Table VI, drainage canal at Lockport.

6206 The table shows that after two days up to ten days no typhoid colonies were found.

Ten minutes after the typhoid bacilli had been introduced varying amounts of the mixture of the sewage and typhoid bacilli were plated in three different media. In one of these cases .001 of a c.c. was plated and there were 45 colonies in all on the plate. Fourteen of these colonies were picked out as looking suspiciously like typhoid colonies and on applying appropriate tests, as already described, 13 of these proved to be genuine typhoid bacilli. From this same sample of water .001 of a c.c. of water was plated and 160 colonies in all developed on the plate. Eighteen of these were picked off as looking like typhoid colonies and 17 of them proved to be genuine typhoid bacilli. Of this same sample .001 of a c.c. was plated in Hiss' medium, 230 colonies developed on the plate, 36 of these were picked off as resembling typhoid colonies and 33 of these proved to be genuine typhoid colonies.

The fact that on these three different media 63 out of 68 colonies that appeared to be like typhoid colonies turned out to be genuine typhoid organisms, demonstrates the great aid that these special media were in differentiating the typhoid bacillus in the presence of a multitude of sewage forms.

I consider this as one of the most remarkable of all experiments that were made. On the 10th day after inoculation 1 c.c. of the contents of the sac was plated in Hiss medium and 85 colonies in all developed on this medium, which is not only very favorable to the growth of the typhoid bacillus but to all

6207 other sewage forms, its inhibitive effect being less than that of other media. Eighty-five colonies in all developed in 1 c.c. of this sewage, and the whole number of 85 colonies was picked off the plate and examined and not one of these proved to be typhoid although 10 days previously when the sac

was inoculated, each c.c. in the sac contained 360,000 typhoid bacilli.

This experiment plainly shows an enormous mortality among typhoid bacilli under these natural conditions in the water of the drainage canal. Examination of one whole c.c. of the water after 10 days shows that of the 360,000 that it originally contained not one was left alive.

6208 Table VII, drainage canal at Robey street. This table shows that colonies were plated from four to fourteen days and no typhoid bacillus found.

6209 Table VIII, drainage canal at Robey street. Colonies were plated from two to seven days inclusive and no typhoid bacillus found.

6210 Table IX, drainage canal at Robey street. Colonies were plated from four to fourteen days inclusive and no typhoid bacillus found.

6212 Table X, drainage canal at Robey street. Colonies were plated from two to six days and no typhoid found.

6213 Table XI, drainage canal at Robey street. Colonies were plated from two to five days and no typhoid found.

6214 Table XII, drainage canal at Robey street. Colonies were plated from two to five days and no typhoid found.

6216 Table XIII, drainage canal at Robey street. Colonies were plated from one hour to eight days. After one hour, after 20 hours, after 28 hours, after 2 days, typhoid found. From three to eight days, no typhoid found.

6218 Table XIIIa, drainage canal at Robey street. Colonies were plated from three to ten days. No typhoid found until the tenth day when three colonies were discovered.

6219 Table XIV, drainage canal at Robey street. Colonies were plated from 20 hours to 9 days. Typhoid found after 20 hours, 28 hours and two days. From two days to nine days, no typhoid found.

6222 Table XV, drainage canal at Robey street. Colonies were plated from four days to ten days and no typhoid found.

6223 By using the control sacs, we discovered that there was no such multiplication of bacteria under natural condition as has long been known to occur in glass bottles in the laboratory.

6224 This is one of the reasons for assuming that the conditions in these glass bottles are more favorable for the life of bacteria generally than in nature, and I have already indicated that one possible reason for this favorable effect is to be found in the nature of the substances dissolved by the water.

Tables A. B. C and D, reproduced on pages 6224 to 6227 inclusive, show results of experiments for the determination of river bacteria. Table A contains records of observations in canal water at Lockport. The initial number of sewage bacteria per c.c. was 470,000. In 3 days this number had sunk to 2,000. The initial number of colon bacillus in one c.c. was from 4,000 to 6,000. In 9 days the number of colon bacteria had diminished to 5; the number of streptococcus in one c.c. was, at the beginning 1,090; at 9 days no streptococcus was found when 10 c.c. of this water was examined.

Table B also shows observations at Lockport, showing a decrease in the number of sewage bacteria, colon bacilli and streptococcus. Table C contains records of observations in the drainage canal at Robey street and shows a decrease in sewage bacteria, colon bacilli and streptococcus. Table D shows observations at Robey street with the same results.

6227 I regard this experiment as being especially interesting in that it shows a slight initial increase similar to what is observed sometimes in the waters of the drainage canal flowing between Robey street and Lockport. This very slight initial increase is, however, followed by a rapid decline, and I would call particular attention to the fact that the initial increase does not amount to anything like what is observed in samples

of this sewage standing in glass bottles in the laboratory.

6228 I regard the evidence presented by these control sacs as confirming altogether the inferences which I have already drawn concerning the naturalness of the conditions in these parchment sacs. The course of events, so far as the death of sewage bacteria and colon bacilli are concerned is precisely the same as what I have been led to consider happens in the river when these sewage bacteria are added to it in Chicago sewage. In both cases there is the same marked diminution in the number of sewage bacteria and in the number of colon bacilli.

6230 Table showing summary of averages for the drainage canal at Lockport, based on the tables already offered in evidence.

6232-3 Summary of averages for drainage canal at North Robey street.

6235 Also made experiments comparing the parchment sacs with celloidin sacs. (Witness describes experiments and results thereof.)

6237 I compared the behavior of sewage placed in parchment and celloidin sacs and kept under the same conditions. Fresh sewage obtained from the 56th street sewer in Chicago was placed in parchment and celloidin sacs, suspended in running lake water in the laboratory. The results showed that a multiplication of the sewage bacteria occur the first day followed in the next 24 hours by a marked decline. The number of colon bacteria and streptococci remain about the same for the first three days and then diminish very greatly.

I sent cultured medium to Prof. Russell at Peoria, which was used by him in his work.

6238 It was found by actual experiment under conditions which I believe to simulate closely those in nature that the typhoid bacillus, introduced into unsterilized Lake Michigan water was recovered four days after inoculation and was not found in subsequent examinations made up to the end of

the fifteenth day. It is probable that specially resistant individual cells might survive longer than appeared to be the case in the experiment described in my testimony, but in my opinion even such highly resistant individuals, if they did exist, would not live more than about twice as long as the time recorded in these experiments. So that I conclude that 8 to 10 days would be a maximum period of longevity for the typhoid bacillus in the water of Lake Michigan, under natural conditions.

These experiments, of which a large number were made with varying numbers of typhoid bacilli introduced directly into the water of the drainage canal, gave generally uniform results. It was not difficult to discover typhoid bacilli during the first two days. Later than that they were never found either at Lockport or at Robey street, with one exception. In this anomolous case, 3 typhoid bacilli were isolated on the 10th day from a single plate in a single sac.

Taking into consideration all of the experiments made in the waters of the drainage canal, and assuming, as before, that specially resistant individual cells might exist, which would live twice as long as those found it is my opinion that typhoid bacilli introduced into the waters of the drainage canal, under natural conditions, would not and do not live in that
6239 situation longer than four days.

Remembering that the upper stretches of the Illinois river are highly polluted with sewage and that considerable additions of sewage are made to the Illinois river at points along its course, I do not believe that bacilli introduced into the Des Plaines or upper portion of the Illinois river would live under natural conditions more than five or six days.

It is my opinion that a typhoid bacillus, discharged from the body of a typhoid patient in Chicago and assuming that such discharges were not disinfected so that the bacillus could pass into the sewers of Chicago and thence into the Chicago river and drainage canal, might live as long as 3 or 4 days after leaving the body of the patient.

From what I know of the rate of flow in the drainage canal
nd in the Des Plaines and upper Illinois rivers, in my judg-
ent such a typhoid bacillus would perish long before Avery-
ille was reached, even at a period of low temperature and
high water.

240 (Witness explains probable reason for the discovery
of typhoid bacilli in one sac after ten days had elapsed.)

241 I found no reason for believing that bacilli live any
longer in the sediment of such sacs than freely suspended
the fluid. In my opinion the colon bacillus can live much
nger in soil than in water but there is evidence that a cer-
in destruction of colon bacilli takes place also in the soil
though not so rapidly as in the water. Dr. Wm. G. Savage,
ho wrote a paper on self-purification of made soil, finds that
e colon bacillus lives for some time in the soil but disappears
time goes on, the ordinary soil organisms invading the ma-
rial and taking the place of colon bacillus. He concludes
hat the gradual diminution and disappearance of the B. coli
this refuse is of interest from the point of view of specific
ntamination. This organism, apparently, rapidly dies out in
ch material. It is a more resistant organism than the ty-
oid bacillus. It is a fair assumption from this that the ty-
oid bacillus, if present in such soils, would also rapidly die
t and that the danger of *specific* typhoid contamination from
building on such made soil can be neglected."

242 (Witness states that the experiment shows that colon
bacillus and streptococcus, disappear in running water.)
my opinion, typhoid bacillus will not live as long in polluted
ter as in pure water because the products of the microbes
e present in more concentrated form in the polluted waters
an they are in the purer waters. The action of these toxic
oducts in their concentrated form is naturally more intense
an where these products are in a diluted condition. In my
inion there would be little material difference as to the

longevity of typhoid bacillus in the sediment of a polluted stream as compared with that in the water of the same

6243 stream. (Witness gives reasons for above statement.) (Witness differentiates between conditions which exist in moist soil and the sediment of a running stream with reference to the longevity of typhoid bacillus.)

6244 Under such circumstances as prevail where the contents of privy vaults are spread upon the surface of fields or vegetable gardens, typhoid bacilli may in my opinion live for many months. Under these conditions there is sufficient moisture present for them to retain their vitality, and at the same time, owing to the lack of continuous layer of fluid, any toxic products of other microbes can not diffuse through the mass and injure the typhoid bacilli. The fact that typhoid bacilli live several months in moist soil does not justify the assumption that they would live for the same length of time in the sediment of a river for the reason that there is slight opportunity in moist soil for the action of the soluble toxic products of saprophytic bacteria upon the typhoid bacilli and as I have stated, there is reason to believe that it is the effect of these soluble products upon the typhoid bacillus in water that causes the death of the latter. The poisons of these bacteria could not influence so profoundly the longevity of the typhoid bacillus in soil. The experiments by Dr. Savage that I have already cited, on the disappearance of the colon bacillus from soil indicate, however, that the typhoid bacillus will probably die out in soil, like its more hardy relative the colon bacillus, although less speedily than in the sediment of a river or in polluted water.

I don't know of any bacteriologist, since the beginning of bacteriology who has demonstrated by any experiment that typhoid germs do live in the sediment of lakes or rivers for a long period of time.

6245 (Referring to the statement made by Prof. Fuller, in his testimony on page 4218 of the transcript of the record, that "there were observers over in Switzerland who made such

examinations with positive results showing the presence of typhoid germs in the sediment of Lake Geneva, I think also Lake Zurich," witness states:) No statements are made as to the methods of identification of these microbes. This was before the Widal tests were used for the identification of the typhoid bacillus, and in view of the fact that no statements are made by this authority regarding his other methods of identificatoin, the mere report of finding these organisms was not a satisfactory one.

6246 Loeffler, in his treatise on water micro-organisms, one of the leading German authorities on questions of this sort, in mentioning Lortet's report of the finding of the typhoid bacillus in the slime of Lake Geneva, puts an interrogation mark after the name "typhoid bacillus," indicating his skepticism as to the correct identification of this microbe. Personally I share this skepticism and am unable to assume, in view of the facts given by Lortet in his report, that this identification was correctly and satisfactorily accomplished.

6247 (Referring to Prof. Fuller's testimony on pages 4218 and 4219, with reference to the longevity of typhoid bacillus, the witness states on 6248 of record:) I do not know of any experiments or observations that demonstrate that typhoid fever can live in the sediment of running streams for a period up to a year. In my opinion, the conditions obtaining in moist soil are very different from those obtaining in the sediment of running streams, and I see no reason whatever for believing that the typhoid bacillus will live in the sediment of running streams for a similar period. I do not know of any published report of an experiment entering into the question of the life of the typhoid bacillus in natural waters as extensive as the experiments which Prof. Zeit, Prof. Russell and myself have made, which has been introduced in evidence.

6249 I have already indicated it as my opinion and to this I firmly hold, that the conditions under which this experiment were conducted imitate natural conditions as closely as it is possible to imitate them in the present state of bacteri-

ology. (Witness states reasons why conditions in the experiments made closely simulate natural conditions.)

6251 It is my opinion that typhoid bacilli could not survive the journey from Chicago to St. Louis under the conditions just mentioned, and I do not believe that such typhoid bacilli would arrive in the Mississippi river in a condition that they could be called a menace to the inhabitants of St. Louis. Infectious matters which the settling basins at St. Louis eliminate, come, in my opinion, from places nearer to St. Louis than Chicago, places situated on the Missouri, Mississippi and Illinois river, within five or six days flow from the intake tower. I don't believe that any dangerous elements entering the sewers of Chicago reach as far as the Mississippi river, and if that is the case, I don't see how the settling basins of St. Louis protect against the sewage of Chicago.

6252 It doesn't seem to me that because a reservoir or settling basin holds thirty days' supply that all typhoid bacilli introduced into the reservoir remain there for 30 days.

6253 (Witness quotes from paper by Dr. Hoeber on experiments of the longevity of cholera and anthrax bacilli in an aquarium. I have investigated several epidemics of typhoid fever in this country, one being at Ithaca, New York, and another at Butler, Penna. I have also as already stated investigated in considerable detail the circumstances of several of the most important outbreaks of typhoid fever that have occurred in the Unietd States. (Witness gives history of the Ithaca epidemic on page 6254.)

They were such sources of infection as one sees frequently in the country districts of this country; overhanging privies and water closets close to the banks of streams. There seemed to be no supervision of the water shed in the way of guarding against contamination by bands of laborers. I should call

the sources of infection in this case distinctively and peculiarly rural.

6255 Witness describes the Butler epidemic.

6256 The Butler epidemic was attributed to rural population. These houses on the Connoquenessing water shed in which the cases of typhoid fever occurred were typical small American farm houses and shanties provided with loosely constructed privies. Discharges from the bodies of patients were thrown, with little attempt at disinfection, either into these outhouses or directly upon the steep rocky hill sides where they remained until washed down into the creek by heavy rains. The class and character of the infection were such as pertain distinctively to rural conditions. I was at Lowell for a short time with Prof. Sedgwick when he investigated the outbreak of typhoid fever in that city, to which reference has been made in his testimony. I visited Stamford, Conn., during the progress of a considerable epidemic of typhoid fever in that town, due to infected milk supply. I have also known something about the conditions in the city of Chicago, leading to excessive prevalence of typhoid fever in this city. In regard to the Plymouth epidemic this was also a case of rural infection. The outbreak was traced to an infection of the water supply with the dejecta from a single typhoid patient which had been thrown out on the hillside and allowed to accumulate near one of the feeders of the reservoirs supply the town with water. There the most of infectious material remained until washed down into the stream by spring floods and melting snows. The Lowell outbreak was also a case of rural infection.

6260 In the interpretation of vital statistics the racial characteristics must be taken into consideration.

6261 It is well known that certain races of mankind manifest inborn powers of weakness or of resistance to the onslaughts of various forms of disease. For example, persons of Irish parentage are much more liable to consumption and pneumonia than Russian and Polish Jews. Any city or any section of a city, therefore, having a large proportion of its popu-

lation of Irish parentage, will have a higher death rate from consumption and pneumonia than a district containing few Irish and a larger proportion of Russian and Polish Jews. By the expression, "mortality percentage method," is meant the method of representing the prevalence or fatality of a disease by reckoning the ratio of deaths from that disease to the total deaths occurring in that population during the period under consideration. It is my opinion that the mortality percentage method may and often does fail to give correct information as to the prevalence of a given disease in a community during any specified period.

6262 This mortality percentage method is distinctly not in favor among sanitarians and epidemiologists here and in Europe. In support of this statement witness reads from Newsholme's Vital Statistics, page 186.

6263 (Witness also gives as an illustration of the fallacious character of the mortality percentage method as not furnishing the correct rule for the interpretation of vital statistics, the records of the city of New York, also of the city of Boston.

6265 (Referring to the testimony of Prof. Sedgwick on page 3540 of the transcript, wherein he states that he used the mortality percentages in fixing the increase in typhoid in St. Louis, witness states:) I have already indicated my reasons for believing that the mortality percentage method is not a valid method. Uncertain as the population factor may sometimes be, the estimation of the death rate on the basis of population does not involve any such fundamental fallacy as that contained in the mortality percentage method, when owing to the fluctuation in the number of total deaths from year to year, it is dealing with two variables and the ratio of deaths from one specific cause to the total number of deaths can not give a true indication of the prevalence of mortality from a specified cause. It is, therefore, my opinion that the mortality per-

centage method is not a valid one to use in estimating the typhoid conditions in the city of St. Louis.

6266 In my opinion the statistics in the health records should be carefully examined and scrutinized as there are considerable differences in the practice of various health boards and organizations in the matter of reporting deaths under various and varying designations.

The ratios of deaths from a specified cause to the population, or what is known among vital statisticians as the death rate, usually considered on the basis of 1,000, 10,000 or 100,000 population, will then give, with a reasonably accurate estimate of the population, a fairly correct conception of the mortality from year to year and from decade to decade.

6267 In my opinion chemistry and bacteriology often afford very great assistance in arriving at a judgment of the character of a river water. It is sometimes true that chemical and bacteriological data are the only data that one can obtain in regard to the character of a given water and while the inferences from the bacteriological or chemical data alone are perhaps rarely final, such data are frequently the only available material upon which a judgment can be founded.

In any case an experienced epidemiologist would attempt to secure chemical and bacteriological data regarding the character of a river water as constituting an important element in enabling him to form a judgment of the water.

Here, in particular, analyses offer a material aid in determining the rate and extent of the process of self-purification. Analyses of a river water, polluted at its source, which are made at various points along its course, make it possible to trace the successive changes that take place in the amount and condition of the organic matter in the water, and in the number and kinds of bacteria.

It is my opinion that correct inferences may be drawn regarding the process of self-purification by the study of such analytical data.

I will reiterate what I have already stated that all sources

of information of any kind, tending to shed light on questions in issue, are valuable to sanitarians and epidemiologists and should be investigated and considered.

(Wtiness states method of ascertaining presence of infectious diseases in various communities, also the ordinary mode of causation of infectious diseases and the chief sources of infection in typhoid fever.

6269 It is not a legitimate inference that because typhoid fever increases in a city, that such increase is due to an increase in the infection of the water supply, unless other sources of infection are eliminated. An increase of typhoid fever in a city may be due of course to an increased infection of the public water supply, but it may also be due to the infection of the milk supply, or an infection of private wells, to special opportunities for the transmission of the disease by insects or to a change in the character of the population, such as the immigration of a large number of persons of susceptible ages, who had not previously lived in the city, and acquired a certain degree of immunity.

6270 Assuming that the reports of the St. Louis Board of Health show an apparent increase in typhoid fever during the years 1900, 1901, 1902 and 1903, as compared with previous years, it is not in my opinion a justifiable conclusion that said apparent increase of typhoid fever in St. Louis is due to any infectious matter passing into the sewers of Chicago and thence into the Illinois and Mississippi rivers, by way of the drainage canal. An increase in the infection of the Mississippi river water from points near at hand would seem to me to afford a more satisfactory and scientific explanation of an increase of typhoid fever in St. Louis than the passage of any

typhoid bacilli into the intake of the St. Louis waterworks from a point so far removed as Chicago.

6271 The specially severe incidence of disease in one district or in one section of a city might be regarded as a special intensity of infection. If there are 1,000 cases of typhoid fever in one ward in the city as compared with 50 in a neigh-

6272 boring ward, with the same population, the infection might be said to be more intense in one case than in the other.

The word intensity might be used, too, I suppose, to indicate severity of individual cases of disease. If among 1,000 cases of typhoid fever in one ward 200 died while in a neighboring ward with the same number of cases only 50 died, the intensity of infection might be said to be greater in the former case than in the latter.

It has been observed that where a community is served by an infected water supply there are often fewer cases of typhoid fever in the periphery of the town at a distance from the central source, than they are close to the point where the water is pumped into the mains. In other words, the greater the distance from the source of infection the less the intensity of the disease. The nearer the source of infection the more severe the incidence.

The observations that I have just alluded to are observations of this character and indicate that the more remote the source of infection the less severe is the incidence of disease.

(Witness states that typhoid bacilli decline in virulence through a prolonged sojourn in water and quotes from authorities presenting the same opinion after investigations which they made, and who also state that typhoid bacilli were found by

them in waters that were not giving rise to typhoid fever.)

6273 By decrease in virulence of a typhoid fever germ, I mean a diminution in its power to invade the human body and bring about pathological conditions.

6274 Typhoid fever is a rural, rather than an urban disease.

6275 It is my opinion that the danger from a rural population can by no means be ignored by any sanitarian or epidemiologist who wishes to take into account all data bearing upon questions of the spread and transmission of infection. (Witness gives figures and instances in support of the above statement.)

6276 (Witness refers to epidemic caused by infection from a rural population.)

6277 (Gives reasons why infection from rural population is to be specially feared.) I have a table of deaths reported from typhoid fever in St. Louis, by months, from January, 1890, to December, 1903, inclusive, and I have a similar table for Chicago for exactly the same period. (These tables are reproduced on pages 6279 and 6280.)

6281 From these tables, I am unable to discover any relation between the monthly deaths from typhoid fever in Chicago and those in St. Louis. An increase in the death rate from typhoid fever in St. Louis is not preceded by a corresponding increase in the death rate in Chicago. A decrease in number in Chicago is not followed by a decrease in number in St. Louis.

6282 If typhoid fever in St. Louis during that period was caused by infection coming from Chicago, I should certainly expect to find some relation obtaining between the prevalence of this disease in Chicago and that in St. Louis.

I should anticipate that in general if the typhoid fever conditions in St. Louis were dependent upon those in Chicago that a large number of deaths from typhoid fever in the latter city would be followed within three or four months by an increase in the number of typhoid deaths in St. Louis.

No such relation appears in the monthly records of typhoid fever of these two cities as tabulated.

It is therefore my judgment that typhoid fever conditions in St. Louis are unaffected by a large amount or small amount of typhoid fever in Chicago.

(Witness refers to water gauge readings at Kamps-ille, Illinois, of which tables have been made.)

6283 From an examination of the tables just referred to, I am unable to discover any connection between the stage of low water as disclosed in the gauge readings at Kampsville, and a large amount or small amount of typhoid fever in St. Louis. In the four years for which record is at hand, absolutely no relation exists between low water in the Illinois river as shown by the gauge readings at Kampsville and an increase or decrease in the typhoid mortality in the city of St. Louis.

6284 From an examination of the monthly deaths reported from typhoid fever in Chicago and St. Louis between 1890 and 1903 inclusive, I am unable to discover any dependence of the mortality in St. Louis upon that in Chicago, as respects extent of mortality, season of year or stages of water in the Illinois river.

6285 Have made a study of the so-called germ diseases in connection with my work in bacteriology.

6286 (States what typhoid fever and malarial fever are and their clinical diagnosis.) (Witness refers also to other types of fevers and states:)

6288 It is generally considered that these designations relate in almost every instance to cases of typhoid fever and that they should be so regarded. It is the general opinion among statisticians that the deaths so classed should be transferred bodily to the column of deaths from typhoid fever since they are practically in all cases deaths from typhoid fever and not deaths from malaria. Malaria in fact, as it occurs in temperate countries is rarely fatal.

(Witness quotes from various authorities tending to show that typhoid malaria and typhoid fever are the same disease.) The number of deaths reported, as occurring from typhoid fever in St. Louis according to the reports of the St. Louis Health Department, in my opinion, certainly do not represent the total number of typhoid deaths actually occurring in that city from the period 1890 to 1903 inclusive.

6291 I find in the records of the Health Department of the City of St. Louis a very considerable number of deaths under the heading "Remittent, Intermittent, Typho-malarial, Congestive and Simple Continued Fevers." I have already given what seems to me adequate reasons for believing that the majority of these, if not indeed all of them, were deaths from genuine typhoid fever and properly should be so classed. Since there is no reason to suppose that these figures do not correctly represent the reports received from the physicians of St. Louis, I see no escape from the conclusion that the value of these statistics to properly disclose the number of typhoid fever deaths occurring in St. Louis was due to an improper diagnosis. The terms "Remittent, Intermittent, Typho-malarial, Congestive and Simple Continued" fevers have a weight of traditional use behind them. Furthermore it is only in relatively recent years that the sure distinction and differentiation of typhoid and malarial fevers has become possible, through the application of laboratory methods. Many of the physicians who received their medical education before these laboratory methods were in vogue do not habitually employ such methods in their practice, and without these modern methods, on the basis of clinical symptoms alone, it is often difficult and indeed well nigh impossible

6292 to differentiate obscure and indefinite types of fever. In my opinion no city in the United States has as large a death rate from genuine malaria as would be indicated by the official records of St. Louis, assuming that all deaths reported under this head of remittent, intermittent fever, etc., were deaths from malaria. (Table read in evidence of page 6293 showing typhoid deaths by each month from 1895 to 1903 inclusive, with

table for same period with the fevers indicated in heading as "Remittent, Intermittent, Typho-malarial, Congestive and Simple Continued fevers." The table shows a close parallel between the number of deaths reported from these two causes—that is, typhoid fever and the other fevers enumerated.

6294 An interesting change is noted in the latter part of this table. For the first five years of the table the number of deaths under the heading B (remittent fever, etc.), was greater than the number of deaths under the heading A (typhoid fever). Beginning with 1901 the reverse is true. The number of deaths reported under the heading typhoid fever becomes greater than the number reported under the heading remittent fever. To take for example the month of September.

6295 Inspection of these figures shows that in the last four years there has been a transfer from the column B, that of remittent fever, etc., to the column A, that of typhoid fever, the effect being to diminish the number of deaths reported as remittent fever, etc., and increase those reported as typhoid fever.

Witness reads table in evidence showing same results as previous table but by years instead of months. This table shows a similar condition to that evidenced in the monthly tables just produced. They show that a much larger proportion of deaths is reported under the heading "Remittent fever, etc., before the year 1900 than since that year.

6296 They also show that whereas the number of deaths reported from typhoid fever was generally less during the first 10 years of this period than the number of deaths reported from remittent fever, etc., during the last four years, the case has been just reversed. It is evident that there has been some cause or that there have been some causes at work tending to produce a more accurate diagnosis on the part of the physicians and that a larger number of cases of true typhoid fever have

been recognized as such during the latter period than during the earlier one.

6297 (Witness refers to circular letters issued by the St. Louis Health Department in the fall of 1900, calling upon physicians to make reports of typhoid fever deaths, etc.) It is certainly in my opinion a significant fact that since 1900 there has been this decided change in the mode of reporting deaths.

6299 There is every reason to suppose that during the first five years covered by these tables a larger proportion of the deaths recorded under the heading "intermittent fever, etc.," were genuine typhoid fever than in the latter period owing chiefly to the progress that has been made in the methods of diagnosis.

(Witness refers to tables and figures by which he attempts to show that the typhoid fever returns made to the city of St. Louis prior to the year 1900 were not complete and that many of the reports of death from intermittent and other fevers, should have been classed under the head of typhoid fever. It is quite important that the testimony of the witness on these matters should be carefully reviewed from the record itself.)

6308 In consideration of all the facts regarding the mortality of typhoid fever in the city of St. Louis during the period indicated that can be obtained from the official records as published it is my opinion that the average annual death rate from typhoid fever in that city has been lower for the four years 1900 to 1903 than for the preceding decade, excluding the epidemic year of 1892.

From the facts already cited which embody all the information that I have been able to obtain, and from a critical analyses of the figures presented in the reports of the health department of the city of St. Louis I conclude that there has been no increase in the annual death rate from typhoid fever in the city of St. Louis since January 17, 1900, as compared with the average annual death rate for the four years preceding 1900. As shown in my answer to a previous question the death rate for these two periods computed on the assumption that the typhoid

fever deaths and the typho-malarial deaths should be considered as a whole, is almost exactly the same.

6309 It is my best judgment based upon all the information of which I have become possessed that no portion of the typhoid fever mortality occurring in St. Louis since January, 1900, can be attributed directly or indirectly to the opening of the Chicago drainage canal.

6310 Running water, like still water, will rid itself of pathogenic bacteria after a sufficient time. The factor of time rather than distance influences the disappearance of pathogenic microbes. There is satisfactory evidence that a flowing stream becomes freed from large numbers of sewage bacteria that are introduced into it, and since many of these sewage bacteria are much more resistant than most pathogenic microbes it follows that the rate of disappearance of the latter is probably more rapid than that of the harmless sewage bacteria. A remarkable instance of the disappearance of sewage bacteria in running water is furnished by the condition of the Mississippi river at New Orleans. Although the sewage of the whole interior of the North American continent enters the Mississippi river and its tributaries, the number of colon bacilli, the most characteristic bacteria of sewage at New Orleans is so small that from this standpoint the water compares favorably with many filtered waters and indeed many pure spring waters. The evidence on the whole is overwhelming that running water, like standing water, can and does purify itself.

It is my opinion that the waters of the Mississippi west of the center of the main channel of the river below the mouth of the Illinois river and down to the intake tower of the St. Louis waterworks at the Chain of Rocks are no less valuable for

6311 drinking purposes nor more liable to carry water borne diseases than they were before the sewage of the sanitary district of Chicago passed through the drainage canal and through it into the Illinois river.

I have seen no reason to think that the added volume of water from the drainage canal would materially affect the

amount of sedimentation occurring at most seasons in the Illinois river, since the speed of the current in the river appears to be but slightly affected by the increased discharge from the drainage canal. The increased volume leads rather to the spreading out of the river into the low-lying banks and subjacent

6312 meadows thus affording additional opportunities for sedimentation rather than leading to a scouring of the channel.

The analyses and examinations that have been made of the water in the Illinois river at its mouth do not in my opinion show that the opening of the drainage canal has caused the sewage from Joliet, Peoria and other towns of the Illinois river to be hurried into the waters of the Mississippi river any more rapidly than was the case before the added volume of water from the drainage canal was poured into the waters of the Illinois.

6313 I do not think that such increased speed as might reasonably be assumed to result from the opening of the drainage canal would increase in any degree the liability to typhoid and other water borne diseases of the inhabitants of the State of Missouri for the reason that such shortening of the time involved as might legitimately be assumed to occur would not come within the range of longevity of a typhoid bacillus under these conditions.

6314 I know of no evidence that indicates that in a sewage polluted stream typhoid bacilli might live for years, months or even weeks. On the contrary all the evidence that I am familiar with regarding the life of typhoid germs in water, even under the very favorable conditions present in sterilized water, in glass flasks in a laboratory shows that this organism is not only able to multiply under thesse conditions, but that it diminishes rapidly and steadily.

6315 In my opinion, and I believe in that of bacteriologists generally, the presence of colon bacilli in water affords a satisfactory clue to the amount and freshness of sewage pollution.

Since it is true that the number of colon bacilli now found in the water of the Illinois river at Grafton is no greater than the number found in the water at this same place before the opening of the drainage canal, I am certainly compelled to conclude that the character of the water and its liability to contain typhoid germs has not been materially changed and that the water is no more dangerous than formerly.

From all that I have been able to learn concerning the life history of the typhoid germ in water, it is my opinion that it is most improbable that typhoid germs would live long enough in the Illinois river to pass from Lockport to Lake Peoria. In case of such an extremely unlikely occurrence any such typhoid germs deposited on the bed of Lake Peoria would in my judgment be in an extremely weakened condition and would

6316 not be likely to live for more than a few hours. It is my opinion that there certainly would be no accumulation of bacilli under these conditions.

Water leaving Lake Peoria cannot at any time contain more living typhoid bacilli than exist in the diluted sewage floating from the Bear Trap Dam.

6317 It is my opinion that typhoid fever germs coming from Chicago sewage rarely, if ever, live long enough to reach Averyville, and it is consequently my judgment that such germs cannot be deposited in large numbers in the lakes and slack water portions of the Illinois river above Peoria. It is emphatically my opinion that the number of typhoid germs in the water of the Illinois river and Lake Peoria is never as great as the number in the drainage canal near the Bar Trap dam at Lockport, and furthermore that the assumption that they are is not,

so far as I am cognizant of the facts, borne out by any data, chemical, bacteriological or epidemiological.

6318 I have studied the facts and read the testimony regarding the dredging of the Black river at Port Huron and I do not consider the cause of the epidemic at Detroit has been established as coming from the Black river.

6320 From all the knowledge that I have, I have formed the opinion that the water of the Illinois river at Grafton does not contain infectious elements derived from the sewage of Chicago, and that consequently such water reaching the Mississippi river and becoming mixed with that water is not a menace to the health of the inhabitants of the State of Missouri, on the Missouri shore of the Mississippi river or to the citizens of St. Louis.

I know of no evidence that indicates directly or indirectly that the waters of the Illinois river at Grafton are infected from the sewers of Chicago, and in view of the large amount of pollution of the Illinois river that takes place at points less remote from its mouth than Chicago, it is my opinion that convincing evidence of such infection coming from Chicago would be very difficult if not impossible to secure.

6323 Assuming that there had actually been a marked increase in typhoid fever in St. Louis since the opening of the drainage canal, which appears to me to be contrary to the fact, it would, in my opinion, be more reasonable and significant to attribute such an increase in typhoid fever to other causes, such, for example, as an infection of the water supply nearer the water intake, to infection of the milk supply or to some other factor rather than to infected sewage coming from the sanitary district of Chicago.

6324 It is my opinion and judgment that the chemical, bacteriological and epidemiological evidence is altogether convincing that the water of the Illinois river at its mouth is no more unsafe and unwholesome now than it was before the opening of the canal, and that consequently the water of the Illinois river since the opening of the canal has not rendered less safe

and wholesome the waters of the Mississippi river below the mouth of the Illinois river.

(The witness in this examination was asked a great many questions that were asked Prof. Sedgwick.)

6329 From all the tables and analyses submitted by me in evidence in this case, assuming that by practical purification is meant the death of typhoid bacilli, in my opinion this purification has occurred before the flow of the Illinois river reaches Averyville. The exact point must vary somewhat with the rate of flow, temperature, number of bacilli introduced, concentration of sewage, etc. The question of self-purification of running streams has been given great attention in Europe and in parts of this country. I have read the statements on this matter by the leading authorities on water supply and river water, published in English, French and German.

6330 (Witness quotes from Dr. Thresh's work on "Water and Water Supplies," which witness states is one of the best known and most authoritative treatises in the English language on water supply.) In order to qualify as a sanitary expert, I should consider that some knowledge of chemistry and bacteriology was absolutely necessary.

6331 It is my opinion that a typhoid bacillus that had remained alive for sixty days in the sediment of a stream or a lake,—a supposition in itself extremely improbable,—would not be virulent and capable of causing disease in man. I base this opinion upon the observations on virulence of typhoid bacilli after a long sojourn in water. Meager as these observations are, they indicate that a decline in virulence does occur. I should like to add that from all the information that I have been able to gather it seems to me highly unlikely that a typhoid bacillus could remain alive and virulent in sediment for a period as long as that designated.

6332 Comparing the Missouri river near its mouth with the Illinois river above Grafton, and the Mississippi river above Grafton, I have no hesitation in saying that I regard the waters of the Mississippi and Illinois, at the point indicated,

less dangerous and less unwholesome than the waters of the Missouri river. Between the Illinois and the Mississippi rivers, at the point indicated, there is, in my opinion, not much to choose from a sanitary point of view.

6333 Such an admixture as occurred of the Illinois river water with the Missouri river water would tend to improve the quality of the water since the number of colon bacilli in the waters of the Missouri river are distinctly greater than those in the waters of the Illinois, and this condition, in my opinion, indicates that the Missouri river water, which is more highly charged with these objectionable bacteria, is more likely to be the vehicle of typhoid fever bacilli than the water of the Illinois which does not contain so many bacteria of this type.

All the analytical data that I have obtained myself and all that I have seen which has been obtained by other investigators indicate both from the chemical changes that take place and from the diminution in the number of ordinary sewage bacteria, and especially in the diminution of the number of bacillus coli communis that under existing conditions, infectious materials introduced into the sewers of Chicago can not and do not pass down the Illinois river as far as Grafton.

The mixing of the Illinois with the Mississippi and Missouri rivers does not create any added danger to the already polluted and contaminated waters of the Missouri and Mississippi rivers below Grafton.

6334 (Witness makes a comparison of the increase in typhoid fever in Washington, D. C., due to an epidemic in Cumberland, Md., with the conditions existing on the Illinois river and the city of St. Louis, and states that in the later instance the conditions are radically different.)

6335 It is my opinion that the typhoid bacillus could not live nearly as long as from one to three years in the sediment of the river or drainage canal.

6336 The pollution that has occurred in Chicago is manifest at the mouth of the Illinois river chiefly in the increased amount of chlorine present in the water of the Illinois river at

that point. The introduction of a large amount of nitrogenous organic matter is also betrayed by the large amounts of various compounds containing nitrogen present in the water of the Illinois river at its mouth, but so far as the original polluting matters and pathogenic bacteria introduced into the Chicago drainage canal are concerned, I can find no grounds for adopting the opinion that these substances and these bacteria persist in their original condition as far down as Grafton.

6338 The dams of slack water basins or lakes in the Illinois river, in my opinion, materially facilitate the process of sedimentation and also serve to retard the current in a not inconciderable degree.

6339 So far as the purification of the sewage of Chicago is concerned, the assumption of the removal of the dams at the places stated would in my opinion not materially affect such purification, since the elimination of typhoid bacilli takes place, in my judgment, in the upper stretches of the Illinois river. It is possible that a removal of said dams might have some effect in retarding the purification of the sewage and the elimination of dangerous bacteria discharged by various communities in the lower half of the river.

The water supply of St. Louis and the water supply of the citizens from the Mississippi river would not be endangered or infected by the sewage of Chicago entering the drainage canal if the four dams before mentiond, in the Illinois river should be removed. In my opinion, those dams have little, if any share in effecting or accelerating the effect of the Chicago sewage.

6340 In my opinion the Mississippi river water at the intake tower at St. Louis was unfit and unsafe for drinking purooses prior to January, 1900. The Missouri river water at Bellefontaine prior to 1900—assuming that the period of storage of such water in settling basins was not greater than three or four days—in my opinion was not fit or safe for drinking and domestic purposes. The Illinois river in my opinion was not a safe water for drinking and domestic purposes prior to the opening of the drainage canal at Grafton.

In my best judgment the sanitary quality has not been materially affected either in the direction of improvement or in deterioration.

So far as I can judge from all the analytical data that have come under my observation the Illinois river water at this time was no worse than the water of the Mississippi river, while the water of the Missouri river was distinctly inferior in its sanitary qualities to both the water of the Mississippi and the Illinois.

6341 Beyond increasing the amount of chlorine and perhaps of some other constituents of no sanitary significance it is my opinion that the sewage of Chicago has had no material effect upon the water of the Mississippi river.

6342 It is my opinion, assigning due consideration to all the facts mentioned, that the discharge of the sewage of Chicago into the drainage canal has had no injurious or detrimental effect upon the health of the inhabitants of St. Louis or the State of Missouri.

6343 Summing up all the experience that I have gained in my studies of the Illinois and Mississippi and Missouri rivers and their tributaries and all the information that I have gained from all sources it is my firm opinion that no relation near or remote, has been traced between the typhoid conditions in St. Louis since January 17, 1900, and the opening of the drainage canal on that date; and it is further my opinion that no such relation exists, and that the opening of the drainage canal was an event entirely unconnected and unrelated with any typhoidal conditions prevailing in St. Louis at that time and has remained up to the present time, unrelated and unconnected with the typhoid fever mortality in the city of St. Louis.

CROSS-EXAMINATION, by Mr. Jeffries:

6345 The best evidence as to water being typhoid infected is the result which it produces upon a community using it for domestic or drinking purposes. (Witness states that typhoid bacilli are never found in suposedly infected water for the reason that the examination of such water is made after the

disease is prevalent and the period of incubation has elapsed and during that time the typhoid bacteria in the water that may have caused the typhoid fever have disappeared.)

6350 In the event that there would be one typhoid fever germ for every pint of water I should not consider that as a highly infected water supply. Nothing is known as to the number of typhoid fever bacilli necessary to produce a case of typhoid fever in man. A laboratory worker attempted suicide through swallowing several tubes of broth cultures of typhoid bacilli but only a mild case of typhoid fever resulted, in spite of the hundreds of millions of bacilli that were taken in this highly infected broth.

6351 This instance of experimental suicide would not have the same effect if undergone by all persons promiscuously. We do not know how widely the susceptibility of different individuals to infection with typhoid fever bacillus varies or upon which such susceptibility depends.

6352 All the experience gained in bacteriological laboratories from inoculation of hundreds and thousands of animals with many kinds of pathogenic bacteria under varying conditions has shown that rarely if ever can one, two or three germs, even when belonging to highly virulent varieties produce infection. It is my opinion that swallowing one or two or a half dozen typhoid germs would not produce a case of typhoid fever in man, basing this opinion on the analogies drawn from laboratory experience.

6361 (Witness is asked hypothetical question based upon table 134, introduced by witness, upon which averages of results of examination of water at Averyville are shown and then asked if, in his opinion, the water at that point has become free from the effect of the sewage of Chicago, as shown by the results of the analyses referred to.)

6362 The large amount of chlorine present in the Chicago sewage as in all sewage makes itself evident in the waters of the Illinois river at Averyville, as shown by the analysis cited. So too does in my opinion the large amount of nitrogen intro-

duced in the sewage of Chicago. It is difficult to see how this could be otherwise. The chlorine is in the form of a stable, mineralized compound, common salt, and suffers little if any diminution in the total amount in its passage down the river. The nitrogenous compounds of various kinds are altered more or less in their passage down stream, and the amount of nitrogen appearing under different heads varies from point to point, and some of that originally introduced into the stream disappears. There is, however, a large amount of nitrogen in the form of its various compounds, free ammonia, albuminoid ammonia, nitrates and nitrites, in the waters of the Illinois at Averyville which has in my opinion come in a more or less changed condition from Chicago.

6363 In the light of all the experience that I have had in the chemical examination of water, and all the information that I have derived from a study of the work, of other investigators, the amount and rate of nitrification in the waters of the Illinois river, from Lockport to Grafton, are such as have been found in the experience of water analysts to accompany the disappearance of disease producing elements.

Answering your question directly I will say that I do not believe it is possible to affirm absolutely from the results of the chemical examinations alone that the water of the Illinois river at any point where I have taken samples and made analysis is free from disease producing elements.

Furthermore, assuming that such disease elements are present in the water of the Illinois river at Grafton, I do not see how it is possible to affirm, on the basis of chemical analyses alone, whether these disease producing elements were derived from Peoria, from Havana, or from some farm house situated two or three miles above the points where the samples were taken. The whole question of chemical water analyses, as I have reiterated, is simply one of deduction made on the basis of past experience. A chemical examination does not disclose the existence or presence of the different disease producing elements in the water.

It simply affords a certain kind of evidence that must be weighed in forming a judgment as to the sanitary quality of the water.

What is true with reference to the chemical condition of the Illinois river is shown by table 134, just referred to, so far as the respective chemical substances are concerned, is also true with reference to all other tables introduced by me, containing the chemical analyses of the water of the Illinois river, that is, that same effect exists, due to the introduction of the Chicago sewage. (Witness testifies relative to the differences that might exist in the determinations made by him and by Prof. Palmer in the various samples of water taken, owing to greater length of time required in transporting samples to Prof. Palmer, difference of methods employed, etc.)

6371 I do not believe that it has been demonstrated that competent analysis and observers have found the cholera germ able to live in sewage as long as from seven to 13 days. It seems possible that some of the experiments to which you refer were conducted not with the genuine cholera germ but with some of these sewage bacteria which there is every reason to anticipate would have a greater longevity than the cholera germ itself. Furthermore, the isolation of a spirillum from a polluted water into which cholera spirilla had been introduced would have little or no significance unless the agglutionation was applied.

6374 As to the effect of the added volume of water from Lake Michigan upon the typhoid germs discharged from the sewers of Chicago, as it passes through the Chicago river and the drainage canal, I have made no experiments upon the life of the typhoid bacilus in sewage taken directly from the sewers of Chicago, as compared with the life of the same bacillus in such sewage diluted twenty times with Lake Michigan water. I have made such an experiment with colon bacilli and I don't believe that such influences would extend the life of the bacillus more than a few hours. Assuming that the sewage of Chicago was discharged into the drainage canal as now and that the water

and sewage passes down the canal for a period of six days, at which time it is discharged into a reservoir from which a
6375 community obtains its water supply, I should not hesitate to consider the water as being free from typhoid bacilli.

6379 I know of absolutely no ground for assuming or supposing that the products of one micro-organism are more injurious to itself than the products of every other micro-organism are to that particular one. Witness is cross-examined as to the experiment made for the determination of the longevity of typhoid bacillus by means of suspended sacs.

6397 I have made a number of examinations of Lake Michigan water during the prevalence of typhoid fever in Chicago prior to the opening of the canal and have several times found more bacteria drawn from the laboratory tap than were found at Averyville and at Grafton.

6399 RE-DIRECT-EXAMINATION, by Mr. Todd.

Investigations have been published on the speed of the typhoid bacillus and other bacteria. These experiments show that from one to five inches per hour would represent the speed with which a typhoid bacillus could move.

6400 In a river flowing at the rate of half a mile an hour the velocity of the current then would be about 5,000 times as great as that of the typhoid bacillus, so that this organism would be helplessly borne along and brought into contact with various toxic substances without being able to remove itself from their neighborhood.

In regard to the nature of these so-called toxic products in water very little is known, as I have already stated in my testimony. They are, however, doubtless in solution and not in the form of concrete solid particles.

RE-CROSS-EXAMINATION, by Mr. Jeffries:

6401 Taking into consideration the enormous number of bacteria and the large number of species discharged into the drainage canal at Chicago and the relatively small number of bacteria found in the water of the Illinois river at Averyville, and taking into consideration also the continuous discharge of

bacteria into the Des Plaines and Illinois rivers between Lockport and Averyville, from the sewers of Joliet, La Salle and from the drains of many smaller streams or places, it seems evident that by far the larger number of germs introduced by the Chicago sewage must have perished long before Averyville is reached. Whether every individual bacterial cell entering the drainage canal perishes before reaching Averyville is a matter difficult to determine. There is this indirect evidence,

6402 however, gathered from the composition of the various streams tributary to the Illinois. These streams, such for example as the Fox, the Sangamon and others, have not received the drainage from Chicago and yet their bacterial content, so far as numbers is concerned, is almost identical with that of the Illinois river at Averyville.

6403 N. MAC L. HARRIS, examined in chief by Mr. Todd: Am assistant in the Chicago University, associate in bacteriology, under Prof. Jordan. (States educational qualifications.) Prepared media used for the concentration of organisms in connection with the experiment made in the drainage canal under the direction of Prof. Jordan. My duties were also the identification of the organisms isolated by Miss Lincoln, who was an assistant.

6405 ERNST E. IRONS, examined in chief by Mr. Todd: Am assistant in the University of Chicago in bacteriology. Have been connected with the University under Prof. Jordan in bacteriology from January, 1897. I did some work in connection with Streams Examination, in the years 1899 and 1900. This work was done in connection with the examination of the Illinois, Missouri and Mississippi rivers. I made bacteriological examinations. (Witness states nature of his work, how samples were received, etc., also states his connec-

tion with the experiment as to the longevity of bacilli in parchment sacs and manner of conducting the experiment.)

6412 I made examinations in the fall of 1902 and until February, 1903, of the Mississippi river at Quincy, for the purpose of determining the presence of bacilli colon communis.

6413 Table introduced in evidence showing results of such examination. Judging from the determinations that I made during the course of my work for the Steel Company, the colon bacillus was much more numerous in the Mississippi river at Quincy than it is in the Mississippi river at Grafton, or of the Illinois at Grafton.

6419 MARY C. LINCOLN, examined in chief by Mr. Todd: Am a bacteriologist.

6420 Did work under Prof. Jordan of the Chicago University in connection with experiment made by him on the waters of the drainage canal.

6421 F. ROBT. ZEIT, recalled for further direct examination by Mr. Todd:

Since I gave my testimony in this case last October, I have made experiments upon the longevity of the typhoid bacillus in conjunction with Prof. Jordan and Prof. Russell. (Witness states the general plan and outline of the experiment.)

6431 In all the experiments made at Ashland avenue, with a surprising similarity we found that during the first 24 hours the total number of bacteria would greatly increase and typhoid bacilli could be found even with the increasing numbers of all bacteria present in the sac. That typhoid bacilli were found for the next day, during which the total number of bacteria greatly decreased and from now on the total number of bacteria continued to decrease except the typhoid bacteria which were found for three days at the most in Chicago river water. It was impossible, after three days in any of our sacs to find typhoid bacilli. There was no difference in the results of the experiments between the parchment sac and the celloidin sac. In both there was great increase of all bacteria

for 24 hours, then the number dropped from day to day and no typhoid bacilli could be found after the third day. In some of the experiments, after two days we found no typhoid bacilli. The longest we ever found them was three days.

6435 In Lake Michigan water the longest that we found typhoid bacilli was eight days.

6437 As result of the experiments I am of the opinion that typhoid bacilli cannot live in the drainage canal or in the Chicago river or in the Illinois river for more than three days.

What is your opinion, based upon all the knowledge which you possess in regard to this experiment, and other experiments made by you, as to whether the typhoid bacilli coming from the sewers of Chicago and entering the drainage canal and from thence into the Illinois river could survive the journey from Chicago to St. Louis, a distance of 357 miles, and be a danger and a menace to the inhabitants of St. Louis using the waters of the Mississippi river at the St. Louis intake, or the residents of Missouri using the waters of the Mississippi river, as it passes along the eastern shore of the State of Missouri, for domestic and drinking purposes?

It is my opinion that it offers absolutely no danger to the citizens of St. Louis and that no typhoid bacillus coming from the sewers of Chicago will live to reach there.

6438 DR. EDWIN C. ROSENOW, examined in chief by Mr. Todd:

Am graduate of Rush Medical College and am an intern at the Presbyterian Hospital at Chicago. I gave Prof. Jordan three strains of bacillus typhosus sometime last October. I got them from three cases of typhoid fever in the Cook County Hospital. (Witness states that the clinical history and diag-

noses of these cases, as given by Prof. Jordan, is correct, etc.)

6439 PROF. F. ROBT. ZEIT, recalled for further re-direct examination by Mr. Todd:

(Gives size of sacs employed in experiment heretofore referred to.) In my opinion a typhoid bacillus lying in the sediment of a polluted stream such as the Illinois river, for a period in excess of sixty days would disappear. There would be no typhoid bacillus present.

6440 The conditions existing in material on the bottom of rivers and lakes by sedimentation must contain organic material and saprophytic bacteria which again would produce substances that would destroy the typhoid bacillus if it was present in just as quick a manner as they do in the river or lake water. In fact I should think that being so much closer in contact with the saprophytic bacteria in the presence of organic material that the quantity of these poisonous substances produced by saprophytes would be even greater and cause typhoid bacilli to die at least as quick if not quicker under these conditions than in flowing water.

From experiments that we have made it would be impossible for bacilli coming from the sewers of Chicago through the drainage canal to remain deposited on the bottom of the Des Plaines and Illinois rivers for a period of thirty to sixty days. Typhoid bacilli die, under those conditions, in three days.

6441 It is my opinion that typhoid bacilli from the sewers of Chicago would never reach the intake at St. Louis alive. My opinion as a bacteriologist, based upon my examinations, is that the Illinois river, bacterially speaking, was less polluted during my investigations than either the Missouri or Mississippi.

During all of my investigations in the past, that has been the case. As the Illinois river is bacterially purer than the

Mississippi river, it could only improve conditions by dilution.

6442 I do not consider that the sewage of Chicago emptying into the drainage canal and the Illinois river, which in turn empties into the Mississippi river, is a menace and a danger to the inhabitants of Missouri, for the reasons stated in my former examinations, that the Illinois river at Averyville was purer, bacterially, than any part of its course from Chicago to Grafton, and that I considered that absolute purification from saprophytic as well as pathogenic bacteria had taken place above Averyville.

The contamination produced by the sewage of Chicago would be all practically removed before it reaches Averyville, according to my investigations and answers in this case, in which I have expressed these convictions at some length. I am speaking now, of course, of bacterial purification and not of chemical substances, but I should judge that also chemical purification has taken place so as to convert dangerous organic compounds into non-dangerous ones, as soon as saprophytic life has again decreased and thereby shows that the end products of organic material have been produced by saprophytic multiplication, and I therefore can not consider this a danger or a menace to the citizens of St. Louis or the citizens of Missouri using the water for drinking and domestic purposes.

6443 CROSS-EXAMINATION, by Mr. Corum:

6447 In the lake water the longset time we found the typhoid germ was eight days. In filtered river water the germs lived two days only—that is filtered through a Pasteur filter. We have done that numerous times now, some of the experiments in fact were finished yesterday nad we know that the filtered river water as it exists now will kill typhoid bacilli in two days—river water containing no bacteria whatever. Having proven that filtered river water, free of all germs, kills typhoid bacilli within two days, and also knowing that the boiling of such river water allows the same bacilli to live a longer time, I conclude that by boiling you destroy certain

poisonous saprophytic products present in the water and that, therefore, in boiled river water the typhoid bacilli will live somewhat longer than they would in filtered river water. Under the same conditions in lake water typhoid bacilli will live eight days in the filtered lake water and have lived fifteen to eighteen days in the boiled lake water.

6448 There is no other way of removing these saprophytic products other than by boiling. I don't think they are eliminated by the running of the stream—they are simply diluted by the volume of water.

If the other streams are polluted with the same material the same saprophytic products are produced which are again harmful to disease producing bacteria. The reason of the saprophytes multiplying more in water than the disease producing bacteria is because the temperature of the water is more favorable to the multiplication of saprophytes than it is to the multiplication of parasites, therefore pathogenic or disease producing bacteria can not multiply in lake or river water. They are not destroyed, if the lake or river water was pure and free of all polluting organic material and therefore free or practically free of saprophytic life. As soon, however, as there is any pollution whatever with organic material you have an increase of saprophytes and an increase of saprophytic products and then the few disease producing bacteria that are present, and that were unable to multiply, are now destroyed by the saprophytic products. I originally thought that this effect of the disappearance of the typhoid bacteria was really due more to the over growth of saprophytes, making the conditions of life for typhoid bacilli unfavorable, than to the saprophytic products which are diffused through the water, but I have convinced myself now by these filtering experiments, that there is in the river water sufficient of these saprophytic products present to destroy disease producing bacteria.

6449 In making our experiments we found that the typhoid germ lived in boiled water in Lake Michigan as long as 15 to 18 days. Such is not the case in the river. In the river,

while they also lived longer in boiled than in filtered water, they disappear sooner so that there must be present in the river water certain substances that are injurious, to the typhoid bacillus which are not destroyed by boiling, although river water is not as deadly to the typhoid bacillus when boiled as when it is only filtered.

6450 Bacteria living, but not multiplying in water do not produce any product.

6452 I have stated the longest time for which we were able to find the typhoid bacillus with the most exhaustive work in detecting them. I think I want to strictly confine myself to the actual findings that I have given here and say that they live that long and that I know by experiment on the filtered water of the river that they die in two days or less and in non-filtered river water in three days or less.

6455 These tests were made in October, November, December and January.

6456 I am quite certain that if these tests had been made in the hot summer months that we would have found them to die sooner yet than what we state here, because the saprophytic multiplication in the summer must be a great deal more pronounced than it was during the time of our experiment.

6457 DR. VICTOR H. BASSETT, examined in chief by Mr. Todd:

(Gives educational qualifications.) The first two years after the spring of 1896 was assistant in chemistry under Dr. Daniels at the University of Wisconsin and the following year I became assistant to Dr. Russell and remained with him one year. After leaving the University of Wisconsin, went to the Johns Hopkins Medical School and was there four years.

6458 Afterwards became assistant to Prof. Zeit in the Medical College of the Northwestern University and assisted Prof. Zeit in the experiment which he made upon the waters of the Chicago river and Lake Michigan, testing the longevity of the typhoid bacillus. (Explains method of conducting the

experiment referred to. On cross-examination, witness testified to the length of time in which he found the typhoid organisms in these sacs, which testimony is similar to that of Prof. Jordan, heretofore introduced.)

6467 PROF. H. L. RUSSELL, examined in chief by Mr. Todd: Am in charge of the Department of Bacteriology in the University of Wisconsin. (States educational qualifications and experience in sanitary work.) Am bacteriologist for the Wisconsin State Board of Health, have made a special study of water analysis, bacteriology, etc.

6469 MR. TODD: Mr. Commissioner, have you compared all the tables and charts introduced in evidence with all the tables and charts contained in the book known as reports of Streams Examinations published by the Sanitary District of Chicago? I ask this question for the purpose of simplifying my examinations as I will refer to Stream Examinations instead of to the individual tables that have been introduced in evidence.

THE COMMISSIONER: I have made this comparison and have found that all the tables and plates printed in the publication referred to have been copied into the testimony in this case by the witnesses who have hitherto testified.

Counsel for complainant makes no objection to this interrogatory or answer.

6470 Have examined and studied the bacterial and chemical analyses of the waters of Lake Michigan, the drainage
6471 canal, the Des Plaines river, the Illinois river, the Mississippi river, and the Missouri river as made by Professors Jordan, Gehrmann, Palmer and Burrill, the same being published in what is known as "Reports of Streams Examinations," published by the Sanitary District of Chicago.

In September, 1903, I made a trip, in conjunction with a number of other individuals, from Chicago to St. Louis, by way of the drainage canal, Des Plaines river, Illinois river, Mississippi river and had given me special opportunities for the physical examination of those streams.

This trip was made by boat from Chicago to Lockport; we then went by rail from Lockport to Joliet, and from Joliet to Peoria on the Rock Island, and then took the Fish Commissioner's Steamer, Illinois, at Peru, and made the continuous passage from there to St. Louis, stopping en route during the night so as to give an opportunity for the physical examination of the stream throughout its entire course by day light. We went up the Mississippi at its junction with the Illinois to Grafton, for the distance of a few miles, so as to observe the physical conditions of this stream before and at its confluence with the Illinois.

6473 In several instances I have found the organism known as bacillus prodigiosus under external conditions. Several of these cases have been in samples of milk which were examined, but in other cases I have found it in water supplies which were reasonably certain to be entirely free from any polluted material. Am acquainted with the experiment made with the bacillus prodigiosus by Dr. Ravold. (Witness is asked hypothetical question that has been heretofore asked witness, assuming conditions said to have existed at the time of the experiment referred to, to which question, witness answers as follows:)

6474 Taking into consideration the assumptions as indicated in the question and also considering the question in the light of all the knowledge which I possess with reference to the distribution of the organism known as bacillus prodigiosus under natural and normal conditions, my opinion is that this experiment does not in any way throw any light on the matter of the probable longevity of the typhoid bacillus as measured by the longevity of the bacillus prodigiosus,

6475 and the assumptions mentioned in the question propounded, leads me to believe it is highly improbable that the organisms reported to have been found on the fourth, fifth and eighth of December at the intake tower, Chain of Rocks, on the sixth and seventh of December were the same or derived from the organisms which were placed in the waters of the

Chicago Drainage canal at Lemont on the sixth day of November.

This conclusion is based upon the fact that a series of examinations made on the samples taken from the water of the Illinois river at Lockport, Joliet, Peoria and Grafton between the 7th of November and December 15th, amounting in all to 1752, and also samples taken from the intake tower at the Chain of Rocks, at the laboratory tap in the city of St. Louis, between November 20th and March 1st, amounting in all to 3120 failed to reveal the presence of the bacillus prodigiosus until 28 days had elapsed from the time the cultures were placed in the river at Lemont.

If the organisms which were reported to have been isolated from the waters of the Illinois river at Grafton and the Mississippi at the Chain of Rocks had been the same or the progeny of the same as those which were deposited in the Chicago drainage canal at Lemont, it would have been natural to expect that in the numerous preceding analyses which had been made, organisms of this species would have been found, as there is reason to believe that the flow of water from Lemont through the Illinois river to the city of St. Louis would not have consumed a period of 28 days.

Assuming that the organisms reported as bacillus prodigiosus, which were found on December 4, 5 and 8th, at the intake tower, Chain of Rocks, and December 6 and 7 at Grafton, were organisms derived from other sources than those due to the depositing of 107 barrels of cultures of the bacillus deposited on November 6th in the river, and assuming that hourly and daily samples were made at these stations along the course of the Illinois river from Lockport to Grafton, and from the waters of the Mississippi river at St. Louis, said analyses amounting in all to 5304, and assuming that in no case were any organisms

belonging to the bacillus prodigiosus found in any of these stations, with the exception of three germs found at the
6476 intake tower, Chain of Rocks, December 4-8, and two organisms found in the Illinois river at Grafton on December 6th and 7th, after a period of 28 days after those 107 barrels of culture had been placed in the Illinois river at Lemont, and assuming the well known fact that the bacillus prodigiosus is a saprophytic organism, capable of living in the water under natural conditions a longer period of time than active, vigorous non-spore bearing parasitic bacteria, such as the bacteria of typhoid fever, it is my opinion that the results of the above experiment show that it is highly probable that the saprophytic bacillus prodigiosus had been destroyed in the waters of the Illinois river during the course of its flow from Lemont to Grafton and the city of St. Louis, and, therefore, assuming that such was the case it would be much more probable that the more delicate and easily affected organism of typhoid fever, entering the waters of the drainage canal of Chicago, from the sewers of Chicago, would not have survived a journey down the Illinois river and Mississippi river to the intake tower, Chain of Rocks, at St. Louis.

As to throwing light upon the question at issue as to the longevity of the typhoid organisms, I do not consider the experiment detailed in the foregoing case, where bacillus prodigiosus were placed in the waters of the Illinois river, would be of any direct value, as the selection of this organism would not give conditions which would permit of a proper interpretation of the results obtained.

It is not uncommon to find in water, organisms possessing the characteristics which simulate those belonging to the prodigiosus. (Witness gives characteristics and pathogenic significance of cholera, tetanus, anthrax, enteriditis sporogenes and dysentery bacillus and also the typhoid germ.)

6480 The typhoid fever organisms is capable of retaining its vitality in soil for a varying period of time, depending upon the influences to which it is subjected and its environ-

ment. When deposited in the soil by burial, the organism rapidly loses its vitality so that at the expiration of a short period, measured by a few days, it can no longer be detected in the upper layers of the soil. When the soil is moist and the organism is deposited in typhoid dejecta, the germ is capable of retaining its vitality for a longer period of time, a period of time which may be measured by months. Some experiments indicate a retention of vitality for five or six months.

The longevity of the typhoid bacillus in water is materially shorter than it is under soil conditions, and here again depends largely upon the conditions of exposure. Where the organism is brought in contact with an aqueous medium with normal saprophytic bacteria, such as would naturally be found where the organism was exposed in sewage or polluted
6481 waters, the vitality of the typhoid germ is greatly impaired, and its longevity is thereby lessened, so that it is my opinion that under such conditions in waters of this character, the longevity of the organism would not normally be more than three or four days or so, but that in waters of a greater degree of purity where saprophytic bacterial life is not so abundant and therefore the vital concurrence between these native bacteria and the typhoid organisms would not be so great, the longevity of the typhoid organisms, under these conditions, would be increased so that it might be found in waters which would ordinarily be deemed as pure waters, even at the expiration of a longer period, possibly one or two weeks.

I have carried out an extensive series of experiments in connection with this matter of the longevity of the typhoid organism. These experiments indicate that when the organism is exposed in water which is ordinarily pronounced as pure and which has first been sterilized by heat and thus deprived of its germ life and possibly of metabolic products of bacterial activity, this process changes the conditions of the water so that in these waters the germs of typhoid fever are capable of retaining their vitality for a period of time, measured by months.

I have also conducted experiments where such water was deprived of its bacterial life by filtration rather than by heat, and under conditions where the soluble products of bacterial growth in the water would be brought in contact with the typhoid organism.

6482 The conditions under which laboratory experiments have been performed on the longevity of the typhoid fever organisms, are, as a rule, more favorable for the prolongation of vitality of this organism, than would exist where the organism was exposed under natural conditions. It has been recognized by practically all investigators on this subject that the organism of typhoid fever lives longer in the sterilized water than it does under raw conditions and if such waters are polluted, if normal raw waters are polluted, it is my belief that the longevity of the germ would be much less in the case of purer sterilized water.

6483 From my knowledge of the conditions which obtain in the water of the Chicago drainage canal and the Illinois river my opinion is that the longevity of the typhoid organism would not be beyond the average more than a few days, at the most, say three or four days.) I have made a large number of experiments on the vital concurrence or competition which would exist when the typhoid organism was exposed under artificial conditions to the influence of various saprophytic bacteria. These experiments have covered a period of four or five years. (Witness details experiments made with celloidin sacs.) These experiments were also made and investigated by a number of my advanced students working under my direction and the results have been confirmatory in a general way. The dams in the Illinois river at low water, where the flow is small, must produce slack water and to a certain extent, cause sedimentation.

6487 The specific gravity of bacteria is only a trifle above that of water. Hence the sedimentation of bacterial cells themselves cannot well occur in pure water freed from all insoluble sediment except in a state of absolute quiescence.

In this connection I have made a large number of experiments on the vertical distribution of bacteria in lakes such as Lake Mendota, at Madison. In the winter when the lake is covered with ice, and therefore there is no disturbing currents due to wind action and temperature changes, the results of these experiments show that the upper layers of the water, although entirely free from the sediment contain a relatively larger

6488 amount of bacterial life and in fact I am unable to ascertain that there is any material settling out of germ life by mere gravitation in waters which are pure, even in a quiescent condition, and much less so that of a running stream.

The reason why bacteria settle to the bottom of a flowing stream depends not on the sedimentation of these organisms, but on account of the subsidence of suspended matter in the stream. The small soil particles, which constitute the mud and silt found in running streams, carry down with them as they fall to the bottom of the stream, a large part of the bacteria which may be found in such waters. In this way the germ content of the muddy water may be very greatly reduced by the sedimentation of its suspended load.

6489 Assuming the present rate of flow to be somewhere in the neighborhood of 300,000 cubic feet per minute with the present amount of sewage discharged, and a condition of turbidity and sediment equal to that reported as existing in the sewage at the time of the analyses as made by Professors Jordan, Palmer and Gehrmann, and reported in Streams Examination, I do not consider that an increase in the amount of Lake Michigan water to a point that would equal a discharge of a million cubic feet per minute over the Bear Trap dam, would permit of entire separation of suspended matter which would be present in the waters of the drainage canal to such a point that the dilution would prevent the sedimentation of such material and the consequent removal in part of the bacterial life in the water.

6491 The dilution of the Chicago sewage, as found in the drainage canal, with the purer waters coming from Lake Michigan would result in a diminution of the number of disease bac-

teria which might be present in Chicago sewage in any given volume, and would thus greatly minimize the danger of infection which might come through the ingestion of the water taken from the Illinois river.

If we consider this question from the standpoint of dilution alone it is evident that the addition of water from Lake Michigan, relatively low in germ content and of a very much purer quality than would exist in the sewage as found in the drainage canal at Chicago, then the addition of this water would be a benefit to the sanitary condition of the water as found in the Illinois river.

If a sufficient volume of water, Lake Michigan water, should be added to the sewage of the city of Chicago and discharged in the waters of the drainage canal, so as to cause an elevation in the waters of the Des Plaines and Illinois rivers to such an extent as would lead to the overflow of the low lands adjoining these rivers, this increase in the volume of water would undoubtedly facilitate the sedimentation of the suspended mater in such localities where this slack water existed.

6492 On account of the fact that the banks of the Illinois river are relatively low it is therefore possible at high water stages for these banks to be easily covered and the widening of the stream during such stages of high water would lead necessarily to a retardation of the current and so cause to be deposited on these low lying lands much of the sediment which would be present in the stream and so would lead to a material sedimentation, and by reason of this fact to a material purification of the water in the Illinois river, when compared with other rivers in which the elevation of the shore was such as to prevent the ready overflow of their banks.

Taking into consideration the conditions which obtain in the Illinois river as to sedimentation and dilution, and all other conditions that can be observed, which permit of the production of chemical and bacterial changes in the sewage, as revealed by the analyses reported in Streams Examinations, I do not consider that the sewage of Chicago, as discharged into the drainage

canal, can have any material effect upon the waters of the Mississippi river except possibly to increase the amount of such undissolved salts as chlorine which are not taken out of solution and which would therefore find their way down the stream and thus probably increase the chlorine content of the waters of the Mississippi river as they pass the shores of the State of Missouri.

6493 Basing the results which have been recorded on the self-purification of flowing streams on the fact that the typhoid organism does not thrive in natural waters, and it is only a question of how long it will live in waters of this class, that the time of flow is so great that pollution dangerous to public health would cease to exist in sewage passing from the city of Chicago to the Illinois river, down as far as the town of Grafton, from the fact that experimental evidence shows that the typhoid organism will not live in highly polluted waters like those of the drainage canal and upper portions of the Illinois river for more than a brief period of time, measured by three or four days, my opinion is that any pollution which would be dangerous to public health which might arise from the sewers of Chicago and enter the drainage canal would not exert any influence on the character of the waters of the Illinois river at its mouth, at the town of Grafton.

The evidence which can be adduced for the justification of the conclusion just expressed rests upon an experimental evidence which has been adduced, which shows that organisms capable of causing typhoid fever will not live in the waters of the Illinois river for a sufficient period of time so that it would have been possible for them to have been carried from the sewers of the city of Chicago down the Illinois river as far as Grafton.

My opinion is that any infectious matters which may be discharged from the sewers of Chicago by way of the drainage canal, are deprived of their infectious properties by reason of the conditions which exist in the waters of the drainage canal and in the waters of the Illinois river before they have had time to have been carried by the waters of said stream from the city

of Chicago down through the drainage canal and the Illinois river to the city of Grafton.

6494 If the typhoid fever is destroyed under natural conditions which obtain in the Illinois river, in the course of three or four days, the stage of water in the Missouri river and the Mississippi river would exert no effect as I can see on the carrying of infected or polluted water from the city of Chicago to the city of St. Louis.

6496 From the knowledge which I have gained with reference to other conditions which exist in the waters of the Chicago drainage canal and in the waters of the Illinois river, together with the evidence which has been presented as to the degree of purification which obtains in that stream, as reported by the chemical and bacteriological examination made of the waters of the drainage canal and Illinois river and the Mississippi river, down to the intake tower at the Chain of Rocks, at the city of St. Louis, I do not consider that the introduction of the sewage of Chicago into the drainage canal exerts and deleterious effect upon the water supply of St. Louis or upon the waters of the Mississippi river as they pass the State of Missouri.

The conclusion that the typhoid organism will not live in the waters of the Illinois river for more than a period of three or four days is based upon an extensive series of experiments which were arranged and planned for conjointly with Professors Jordan and Zeit and myself, but carried out independently. These experiments were designed to show how long freshly isolated typhoid organisms would actually live under conditions as they obtained in the drainage canal and in the waters of the Illinois river.

(Witness explains and gives full details of the experiment made to determine the longevity of the typhoid germ. The

experiment made by this witness was in water of the Illinois river at Averyville, Ill.)

6503 15 different parchment sacs were used.

6509 From sac No. 1, from plates made 24 hours after sacs had been immersed in the water, 12 colonies were removed, one of which was found to be typhoid. (Witness gives results found in each sac at each examination made thereof.)

Summarizing the results obtained in the foregoing an-

6512 alyses 72 colonies were examined from the different sacs after they had been exposed in the water for 24 hours and of these 43 were found to be typhoid. These 72 colonies were taken from 8 different sacs, and in these 8 sacs the typhoid organisms were found in 7 of these sacs.

6513 Of the 25 colonies which were examined on the second day, 12 were found to be typhoid.

These 25 colonies were removed from 2 sacs, both of which contained typhoid.

Of the 44 colonies removed on the third day 14 of them were found to be typhoid.

These 44 colonies were taken from 5 sacs and the typhoid organisms was found in three out of five of these sacs.

41 colonies were taken off on the 4th day, from 4 different sacs, and in none was any typhoid colonies found.

61 colonies were removed on the 5th day from 6 different sacs and in no case was typhoid found.

28 colonies were taken from 3 sacs on the 6th day, and none proved to be typhoid.

32 colonies were taken from 6 sacs on the 7th day, none of which was typhoid.

18 colonies were taken from 2 sacs on the 9th day, 1 of which proved to be typhoid.

On the 10th day 5 sacs were examined, 46 colonies being removed, no typhoid found.

In 7 sacs taken on the 12th day, 38 colonies were examined, none were found typhoid.

In 3 sacs examined on the 14th day, 25 colonies were removed, none were typhoid.

From 2 sacs examined on the 16th day, 14 colonies were removed, none of which were typhoid, and in 1 sac examined on the 17th day, 15 colonies were taken off, none of which were typhoid.

In these particular series of experiments, 459 colonies were examined. The different sacs which were employed were tested 54 times and the typhoid organism was found fourteen times, 70 colonies out of the total 459 belonging to this organism.

During the first 3 days, 141 colonies were fished off, 69 of these were found to be typhoid and in the 318 cases which were examined after 3 days only 1 typhoid organism was found.

I have prepared a table of summaries showing the results, which is reproduced on pages 6514 and 6515.

6516 In addition to the series which were made with the parchment sacs another method was used which approached the problem from a different point of view. Ordinary commercial agar was taken and washed in running water for several days, to remove all soluble products. From the prepared agar small rectangular blocks were cut out. These blocks were inoculated with freshly grown typhoid cultures by means of a platinum wire and the top of the block was sealed by means of searing the surface with a hot iron. According to Oswald, the eminent German physicist, this soluble agar possesses the property of allowing diffusion to take place quite as rapidly through its substance as would be the case in water itself. Hence it follows that if typhoid organisms were placed on the interior of an agar mass and then exposed in an aqueous medium containing bacteria of various kinds, then the typhoid organism would be subjected to the influences which would arise from the growth and development of these water or sew-

age bacteria in the surrounding media in which these agar blocks were immersed.

6518 The summary of the results of these cultures on the vitality of the typhoid fever organisms, inoculated in numbers, so large that the number of organisms produced turbidity to be recognizable with the unaided eye, that the exposure of these numerous typhoid organisms in the waters of the

6519 Illinois river and also in the waters of Lake Mendota at Madison, resulted in loss of vitality of this enormous number of typhoid bacteria to such an extent that in no case were any typhoid organisms found after the eighth day and in the case of one series none was found even on the first day. This variation in the vitality of the typhoid cultures, where an indefinite number of organisms were inoculated, under these conditions, and where it was not exposed directly to the competition which exist between water and sewage bacteria and the typhoid organism is more surprising as the organism was not directly exposed to the influences of the competing bacteria themselves but merely to the soluble products which these germs are capable of producing.

In the case of the parchment sacs the typhoid bacteria were exposed to the direct contact of all the water or other bacteria which might be present in the samples of water which were placed in the sacs. In the case of the agar blocks the typhoid organisms were not exposed to this direct contact but were exposed to those products of the metobolic activity of water and other bacteria which might be present in the outside medium and which would find it possible, if in solution, to pass through the agar block, by diffusion, and so possibly act upon the typhoid bacteria themselves which were screened by these agar blocks.

6519 I find that the experiments made with the agar blocks give more favorable conditions for the retention of the vitality of the typhoid organism than was the case in the

parchment sacs where the contact of typhoid organisms with other bacteria was rendered possible.

6520 I should consider that the typhoid organisms deposited in the waters of the Chicago river and drainage canal would have a much shorter duration of vitality than in waters of Lake Michigan and that such vitality would not extend to a period of more than two or three days. From the results obtained in this combined experiment with Prof. Jordan and Prof. Zeit I should say that the longevity of the typhoid organism immersed in the waters of Lake Michigan would be considerably longer than in the waters of the Chicago river and the organism would probably be able to live for a period or six or eight days.

From experiments which I have actually made when freshly isolated cultures of bacillus typhosus were exposed in permeable sacs in varying numbers so that the germ content of the typhoid organism exceeded at least the germ content of the water used in the ratio of 100 to 1 or more, and where the organisms were destroyed in the course of about three days,

6521 with one possible exception, and that if this was the condition which was obtained under the conditions in which the experiment was made, when the effect of other environmental factors were excluded, such as the influence which would come from sedimentation, dilution, influence of light, vital concurrence with green plant forms which might be found in the waters of such river, I should certainly consider that the life of the typhoid organisms when subjected to the more severe conditions which obtain in the waters of the Illinois river itself than was the case in the experiments with the parchment sacs, that it certainly would be no longer in the waters of the Illinois river and in all probability would be shorter, hence I would conclude from the foregoing data that the vitality of the typhoid organism would not in any case be

maintained for more than a period of a very few days, three or four at the outside.

6522 In view of the above experiments and other conditions, I am of the opinion that typhoid organisms finding their way through the sewers of Chicago, into the Chicago river and thence into the drainage canal, down the Des Plaines and into the Illinois river would be destroyed before such water had passed the course of the Illinois river.

6523 I would consider that if the longevity of the typhoid bacillus be impaired by the action of sewage and the water bacteria of a polluted stream that at least the same, if not a greater effect would be produced if the typhoid organism was in contact with these bacteria and the products of their growth in the sediment of such a stream.

6524 The colon bacillus in ordinary soil which is not saturated completely with water is able to live longer than it is in the water itself.

6526 I do not think that the typhoid organism would live as long in the waters of the Illinois river under the conditions as they exist in nature as would be the case in the waters of Lake Michigan.

6528 There is no evidence which I know of, that indicates that the typhoid organism would be capable of living in the sediment of a polluted stream for a longer time than it would in the water of the same stream.

The conditions which obtain in moist soil and the sediment of running streams are materially different. In the one case the soil is not completely saturated with water for the soil particles are surrounded by a hygroscopic film which adheres to the particles themselves, but gives a considerable amount of pore space in the interstices which is filled with air. In the sediment found in running streams or lakes this condi-

tion would not obtain as these spaces are entirely filled with water.

6529 It is my opinion that the conditions which obtain in a moist soil would not furnish any criterion for the determination of the longevity of the organism as found in the sediment of a running stream. The two conditions as found in a moist soil and in the sediment of a running stream, for the foregoing reasons, are not comparable. In view of the fact that the conditions under which typhoid organisms would be exposed in moist soil are different from those which are found in the sediment of a river, I would not consider that this would justify the assumption that it would live as long in the sediment of a river as would be the case if the exposure was made in moist soil.

6530 On the basis of the experiments which I have been able to perform on the vitality of the typhoid organism when exposed to the waters of the Illinois river, and in view of the facts that the conditions which obtain in the bottom of that stream are such as would undoubtedly bring the typhoid organism in contact with even large numbers of water and sewage bacteria, and the products of their growth, that would often be the case in the waters of the stream itself, it is my opinion that the longevity of the typhoid organism when exposed in the sediment, as found in the Illinois river, would certainly be no longer than it would in the superincumbent water above, and that it is quite possible that their longevity might even be shortened.

6531 From all of the experiments which I have made on the conditions which obtain where the typhoid organism is exposed in the Illinois river it is my belief that this organism will lose its vitality in the conditions which would obtain in the waters and in the sediment of such a

stream in a relatively short period of time, that period of time not exceeding more than three or four days.

6532 Regarding the testimony of Prof. Fuller, to the effect that there are observers in Switzerland who made examinations with positive results showing the presence of typhoid germs in the sediment of Lake Geneva, it is my opinion that these experiments were either carelessly performed or not carried out with sufficient detail, and under sufficiently stringent precautions to warrant the conclusion which is drawn. (Witness gives reasons for this opinion.)

6538 By reason of the fact that the previous experiments which have been detailed, show that the vitality of the typhoid organism is destroyed in the course of not to exceed four days, and that the extent or period of flow which would be necessary for the sewage of Chicago entering the drainage canal to pass from Chicago to St. Louis, a distance of 357 miles, would be so great that it would be impossible for the typhoid organism to survive this journey, it is my opinion that the diffusion of such bacilli in the waters of the drainage canal would not be a danger and a menace to the inhabitants of St. Louis, using the water of the Mississippi river for drinking and domestic purposes. Inasmuch as the typhoid organisms deposited in the city of Chicago and finding their way

6539 into the drainage canal would be killed before the waters filled with such sewage would find their way from Chicago to St. Louis, I must say that the settling basins of the city of St. Louis would afford no protection to the citizens of St. Louis against the sewage of Chicago. The protection which would be afforded to the citizens of St. Louis by passing water through the sedimentation basins, would be from those places adjacent to St. Louis, in which the typhoid organism would not be killed during the journey from such places to the sedimentation basins of the St. Louis supply.

6540 I would not consider that because a basin holds a water supply sufficient for thirty days and that typhoid fever resulted from the use of such water, that the typhoid fever

organism lived for that period of time. I have examined the typhoid statistics of the Illinois, Missouri and Mississippi watersheds above St. Louis and also the mortality statistics of St. Louis, and the typhoid statistics of Chicago and St. Louis. In interpreting the mortality statistics from typhoid fever in St. Louis, it would be necessary to take into consideration the typhoid statistics obtained on or about these watersheds which contribute water finding its way into the Mississippi, past St. Louis, laying special emphasis upon those statistics, which are from cities nearest to the city of St. Louis.

6541 There are two methods that are employed, one which is used largely for comparative purposes, known as the mortality percentage method, in which the death rate from any given disease is figured and determined in terms of the total number of deaths in that community. The other method, which is more generally used, and considered more reliable, determines the ratio which exists between the number of deaths from any given disease, based upon the actual population from which the death statistics are collected. This is known as the death rate from that disease, per unit of population, usually given in terms of 10,000 to 100,000 persons. I regard the latter method as the preferable method to follow in determining the death rate from any given specific disease and it should be followed wherever possible. The method of determining the death rate from any given disease by comparing the mortality of that disease with the total mortality of the community instead of the population itself is liable to introduce error into the results which might readily vitiate the accuracy of such statistics to such an extent as to render them all of much less value than otherwise would be the case. The reason for this is, that when you compare the deaths from any disease, to the total deaths, in order to study the increase or decrease of any disease in any

community, you are using a wrong basis for comparison. What is wanted in any given community is to know whether

6542 a disease is increasing more rapidly than the increase in population. When this rate is based on the ratio between that disease and the total death rate the variation which might and often does occur in the total death rate may be subject to many conditions which now enter into the consideration of the disease in question. Suppose, for instance, that a serious epidemic of some other disease, like the Bubonic Plague, or yellow fever, should break out, it would be manifestly improper to compare the typhoid death rate in that community before and after such an epidemic and compare the actual number of typhoid deaths, with the total number of deaths, and say that the typhoid was increasing or decreasing, where such a fallacious method was employed.

In view of the fact that the urine of typhoid patients often contain bacilli in great abundance, and in view of the fact that this material is not ordinarily looked upon as dangerous, and therefore is frequently thrown upon the surface of the ground, and in view of the fact that in rural communities greater carelessness prevails in regard to the disposition of this excreta, and even solid material, than would be true where special systems of sewage disposal were present, it naturally follows that the liability of the population to the infection of the river is added to considerably from the rural population.

It is a well recognized fact from statistical evidence, that the percentage of infection designated as typhoid fever mortality at least is not less common among the rural population than in urban communities.

6543 There are a considerable number of typhoid epidemics which have been reported in which the sources of pollution have been traced specifically to infection arising from the

rural population. (Witness gives instances of such epidemics.)

6544 The analytical evidence which can be gathered from the analyses of waters taken at frequent intervals for a considerable period of time and at various points along the course of the stream, give us the best possible means which we have at our command at the present time, of showing the progress of the self-purification which occurs in such running streams where organic matter is gradually disposed of and converted into mineral material.

I should consider that the data furnished by bacteriological study, and to some considerable extent, that of chemistry, are the foundation on which a sanitarian or epidemiologist must base his conclusions as to the character of any waters and their liability to be a source of danger and menace.

(Witness gives ordinary modes of causation of infectious diseases and the chief sources of infection in typhoid fever.)

6545 It is very important in making any study of any epidemiological question that the sources of infection should be taken into consideration as well as the results of the infection, for the distribution of the disease, and its dissemination may depend largely upon how the organism finds its way into the human being. It is by no means a legitimate inference that because typhoid fever increases in a city that such increase is due to an increase in infection of the water supply, for it has been abundantly proven in a considerable number of cases, that the organism of typhoid fever is capable of being introduced into the body in other ways than through the medium of infected water.

6546 Assuming that the reports as to the typhoid death rates for the city of St. Louis, for the years 1900 to 1903, are true, and taking into consideration the conditions which obtain in the watersheds of the three rivers mentioned, and the fact that there are sources of pollution from which typhoid organisms might arise which were not as far removed from the city of

St. Louis, as would be the case of the city of Chicago, and taking into consideration further, the results of the typhoid experiments which have been made, and which have been detailed in the foregoing answers, I should say that there was no scientific reason which justified the conclusion that the increase of typhoid fever in St. Louis as reported in the Board of Health reports for the years 1900 to 1903 inclusive, is due to infectious matter which is derived from the sewers of Chicago by way of the drainage canal.

6548 (Witness gives clinical diagnosis of typhoid fever, also intermittent fever, remittent fever, typho-malarial fever, congestive fever and simple continued fever.

6549 The terms remittent, intermittent, typho-malarial, congestive and simple continued are relics of old methods of description which attempted to differentiate these febrile changes, merely on the basis of the symptoms which are most evident. They are not recognized by working bacteriologists or clinicians of the present time as being satisfactory names for specific types of fevers.

The use of the terms remittent, intermittent, typho-malarial, congestive and simple continued as applied to vital statistics collected under present day conditions would in my judgment indicate that the causes of deaths were not classified as they should be and would therefore lead one to place less reliance on such statistics than would be the case if they were more accurately classified.

6550 (Witness is asked hypothetical question, giving the number of deaths from typhoid fever in St. Louis, as evidenced by the annual reports of the Health Department from 1890 to 1903 and also for the same period, the deaths from remittent, etc. fevers.)

From the study of the statistics mentioned in the foregoing question and from the general knowledge of the relation which these diseases bear to each other and the liability of

making an improper diagnosis between them, I do not consider that the number of deaths reported in the vital statistics

6551 of the Board of Health of the city of St. Louis for the years 1890 to 1903 inclusive, represent the total number of deaths from typhoid fever which actually occurred in that city in that interval.

Taking into consideration the fact which is well recognized by sanitarians, that fevers classified under the heads of remittent, intermittent, typho-malarial, congestive and simple continued are in a large measure found to be fevers which by means of modern diagnostic methods would be recognized as typhoid fever, it is my opinion that the statistics which include a large proportion of fatalities as due to fevers of this class, do not represent the true condition which obtained in that city with reference to the total typhoid death rate.

6552 No city of the United States has as high a death rate from pure malaria alone as is represented in the number of deaths reported in the St. Louis statistics. It is probably true that a large proportion of the deaths reported as being caused by remittent, etc. fevers, should be classed as being caused by typhoid fever. Considering the low rate of mortality from genuine malaria in the United States and other facts, as heretofore stated, the deaths resulting from remittent, etc. fevers, placed in Column B should be placed under the head of typhoid fever in Column A. Assuming that the totals of Columns A and B were added together and that the result shown by the addition of those two columns represents the actual typhoid mortality, I should consider that the said statistics do not show material alteration which could be deduced with certainty in the typhoid fever mortality of the city of St. Louis. In comparing the statistics assumed in the foregoing answer, I should consider that the letters sent out by the Health Commissioner

of St. Louis under the caption of typhoid fever alone, I should consider that the actual number of typhoid deaths which have occurred in St. Louis since the year 1900 shows no increase over the death rate in that city from this disease for the period mentioned prior to that time, with the possible exception of the recognized epidemic which occurred about the years 1892.

6560 In the operation of natural courses running water undergoes processes of purification, and frees itself from pathogenic organisms in due course of time.

If the typhoid organism is killed out in the Illinois river in the period of time which is less than the necessary time for the flow of the water from the sewers of Chicago to the city of St. Louis, and assuming that the destruction of the typhoid organism is an index of the destruction of pathogenic organisms in water, and on the basis of the experiments which have been previously detailed in which proof is adduced to show that the vitality of the typhoid organism is destroyed in a much less time than is necessary for the flow of water from Chicago to St. Louis, it is my opinion that the waters of the Mississippi river west of the center of the main channel of the said river and below the mouth of the Illinois river, down to the intake tower of the St. Louis waterworks at the Chain of Rocks,

6561 is not less valuable for drinking purposes and not more liable to carry water borne diseases now than it was before the sewage of the sanitary district was run into the drainage canal and through it into the Illinois river.

An increase in the speed of the current of the Illinois river, by reason of the added volume of water in the drainage canal would probably alter the manner of sedimentation that would occur in the waters of the Illinois river from what was the case before the addition of such water from the drainage canal occurred. The addition of this added volume of water from the drainage canal carries with it a larger amount of suspended organic matter, and therefore increases the amount of suspended material which would be present in the waters of the Illinois river and consequently the addition of this added

and the agitation by the public press as to the opening of the canal, manifest themselves in these statistics.

6557 Owing to the liability to confusion which must of neces-
sity exist from the use of old traditional terms which are descriptive more of the symptoms than the specific nature
6558 of the disease in question, and the direct liability of the confusion of these terms with that of typhoid fever, I should consider that from the standpoint of the bacteriologist, clinician or statistician, in order to get at the true typhoid mortality which would exist in the city of St. Louis, that it would be necessary to add to the statistics which they have reported as typhoid, a large proportion at least if not practically all of the cases which have been reported under the caption which has been designated in previous questions as Column B, to those figures in the given typhoid fever cases.

Taking into consideration the fact that the circulars issued by the Board of Health of the city of St. Louis have unquestionably had their influence in increasing the accuracy of the typhoid statistics since the issuance of that circular in 1900, and that the great majority, if not practically all of the
6559 deaths reported before the year 1900 under the head of remittent, intermittent, congestive, typho-malarial, and simple continued fevers were actually cases of typhoid fever, and, therefore, should have been included in any statistics which showed the total amount of typhoid fever in the city of St. Louis for that time and assuming the accuracy of the compilations which have been made by Professor Jordan, based on the relative increase of population as determined by Farr's formula when to the typhoid fever death rates there have been added from 50 to 100 per cent of all recorded deaths which have been reported under the head of remittent, intermittent, congestive, typho-malarial and simple continued fevers, and which in my judgment represent data showing the actual amount of typhoid fever which did occur for the periods mentioned much more correctly than is shown by consideration of the reported deaths, as reported in the Board of Health reports of the city

drainage canal water would increase the amount of sedimentation which would otherwise occur.

The increased speed of the current in the Illinois river if it did not cause an overflow of the banks of the stream, the increase in the speed of the current would carry suspended matter farther down stream, but it is my opinion that the removal from the river of the sewage from the towns mentioned would be performed before such sewage reached the Mississippi river, so that it would not materially alter the condition of the Mississippi river, except in the case of suspended salts, such as chlorine and nitrates which are not eliminated from the water in the purification of the sewage which might be discharged into such stream.

6562 From the facts of the experimental evidence which has been previously adduced that the typhoid organism would fail to live for a period of time which would be covered by the flow of water from Chicago to St. Louis, it would therefore follow that an additional volume of water discharged by the waters of the drainage canal, which would cause an increased speed in the current of the Illinois river, would not have any effect in increasing or diminishing the typhoid fever or the liability of the inhabitants of the State of Missouri using the waters of the Mississippi river below the mouth of the Illinois river to contract from such waters typhoid or other water borne diseases.

6564 I consider the assumption that typhoid fever could pass from the sewers of Chicago, by way of the drainage canal to Lake Peoria, and be deposited there in the bed of that lake for a period of one month as one that is untenable and in the light of experimental inquiry not in accord with the facts, and it is my opinion that under no normal conditions which could obtain in nature as they now exist that the typhoid germs would

be able to pass from Chicago to Peoria and not be destroyed before the end of the period covered by the question.

6565 Taking all of the conditions into consideration that obtain in the drainage canal, the Des Plaines and the Illinois river, as to the probable longevity of the typhoid bacilli in the waters of such stream, I should consider that at no time under natural conditions would such conditions exist as would cause the waters of the Illinois river leaving Lake Peoria to contain more infectious and dangerous pollution than would exist in the diluted sewage of the drainage canal, passing the Bear Trap dam.

Considering all of the conditions involved, and for the reasons previously explained, I should say that my opinion is that at no time, under natural conditions would the number of typhoid organisms even be as great at Lake Peoria as they would be at the Bear Trap dam.

6566 It is my opinion that typhoid bacillus lying in the sediment of a polluted stream for a period in excess of sixty days would not be able to produce typhoid fever.

6568 Owing to the fact that the pollution or infection which would be deposited in the Illinois river from the sewers of Chicago would be practically purified by the time it has been carried for a portion of its way down the river on the way from Chicago to Grafton, it would naturally follow that the waters of the Illinois river which entered the Mississippi river at Grafton would not be a menace to the inhabitants of the Missouri shore on the Mississippi river if such water was used for drinking purposes at points below on the Missouri shore.

6569 I would not consider that the admission of the waters of the Illinois river would cause any menace to the inhabitants of the Missouri shore when the waters of the Illinois river were discharged into the Mississippi and commingled

with the waters of the Missouri river and Mississippi river, and when the waters of the united streams was used for drinking purposes by persons living below Grafton on the Missouri shore.

The chemical and bacteriological evidence which has been secured in this case through the experimental and observational data which have been presented justify, in my judgment, the conclusion that the waters of the Illinois river at Grafton show no indication whatever of unpurified sewage from Chicago that has found its way from Chicago to the latter place.

6571 Taking into consideration the time involved in the flow of water from Chicago to St. Louis, and in view of the evidence which I have previously presented in combination with others that the typhoid organism is incapable of retaining its vitality for the period of time assumed in the foregoing question, I would say that I know of no evidence based upon any analysis, experiments or otherwise that would justify the assumption that typhoid organisms deposited in the Chicago drainage canal will pass by way of the Illinois river into the Mississippi river and find their way into the water supply of the city of St. Louis at the intake tower at the Chain of Rocks.

6572 Taking into consideration the knowledge which I possess with reference to the conditions under which the typhoid organisms would be capable of living when deposited in the waters of the streams mentioned in the foregoing question, and taking into consideration the fact that other conditions exist which are necessary to consider in considering the question of typhoid fever in St. Louis, it is my belief that I would not consider, beyond a reasonable doubt, the typhoid death rates as occurring in the city of St. Louis (assuming that there has been such an increase since the opening of the drainage canal) to any influence which might arise from the introduction of the sewage of the sanitary district of Chicago into

the Illinois river, and which would find its way down the channel of the Illinois river to St. Louis.

6573 It is my opinion that the deposition of sewage of Chicago into the drainage canal does not increase the longevity of the typhoid organism deposed therein, but on the contrary is a potent factor, toward the more rapid destruction of the vitality of the typhoid organism than would be the case if such sewage was not so deposited. When sewage is added to the water in an unsterilized condition such as would exist when normally deposited in drainage canals, the addition of such sewage does not increase the longevity of the typhoid organism, but on the other hand, is a distinct factor in the early death of the typhoid organism. (Witness states the effect of increase of population in the sanitary district to 5,000,000 people and increased flow in the drainage canal to 1,000,000 feet per minute.) Assuming that a typhoid fever epidemic of extraordinary proportions should prevail in Chicago, no effect would be produced upon the people who use the Mississippi river water for drinking purposes.

6575 Taking into consideration the chemical and bacterial knowledge which has been derived from actual experiment and also all knowledge which I possess with reference to the conditions which would obtain when the sewage of Chicago was placed in the drainage canal, and taking into consideration the possible variation which would exist at different seasons of the year and the influence which different stages of water would exert upon the vitality of disease organisms which might be present in such sewage, it is my opinion that the introduction of such sewage into the Illinois river would not be a danger and a menace to the inhabitants of the State of Missouri and the citizens of the city of St. Louis who might use the waters of the Mississippi river at the intake tower, Chain of Rocks.

6576 From the analytical data which has been presented, it is shown that the addition of the sewage of Chicago to the waters of the drainage canal results in such a degree of purifica-

tion that I do not think that deleterious substances or infectious matters capable of producing disease would be found in the waters of the Illinois river at the city of Peoria, which were derived from the sewers of the city of Chicago. The dams in the Illinois river are an aid to sedimentation and such sedimentation results in the elimination of a large proportion of the total bacterial life.

6578 The water of the Mississippi river at the Chain of Rocks prior to January, 1900, was not to be regarded as a thoroughly safe and potable water supply suitable for all domestic and drinking purposes. (Same as to the Missouri river, and as to the Illinois river.)

6579 I do not consider that the waters of the Illinois river at Grafton should be looked upon as a perfectly safe supply, regardless of the possible changes which have been made by the opening of the drainage canal.

6581 In view of the fact that the conditions which obtained in the city of St. Louis and the conditions of the watersheds which are immediately adjacent to this city, in view of the fact that the typhoid fever death rate in that city is dependent upon other conditions than those due to the water supply of that city, and may be materially influenced by operation of many other factors, in view of the conditions which obtain in the Illinois river with reference to the process of purification which would occur in the sewage of Chicago when deposited in the drainage canal, and taking into consideration all the knowledge which I possess with reference to all data which bear directly or indirectly upon the question involved, it is my opinion that the increase in the typhoid deaths, as reported in the city of St. Louis, assuming such increase to be true, which have occurred since the opening of the drainage canal, can not beyond all reasonable doubt be attributed as a direct, immediate and approxi-

mate cause for said increase to the opening of that drainage canal.

CROSS-EXAMINATION, by Mr. Jeffries:

6582 I consider that it is possible to arrive at a satisfactory examination of a water supply on the basis of chemical and bacteriological methods without necessarily taking into consideration the matter of population.

6585 The colon organism is a normal inhabitant of the intestinal tract of higher mammals and other animal forms, and therefore its mere presence in surface water—this fact taken simply by itself—can not be regarded as direct evidence that its presence had originated from human excreta.

6586 The conditions to which pathogenic bacteria are subjected in nature are such as to produce a rapid loss in vitality of those organisms and consequently a water may be of such a character as to result in a production of disease and if the examinations are not made in large numbers at that particular time the organisms of a pathogenic character may lose their vitality to such an extent that the determination of their presence and not the number of the pathogenic organisms present may be fairly considered as indicating the probable nature of that water as to the liability of producing epidemic disease.

6587 In my routine analytical work the practice is never followed of making a direct examination of such waters as are ordinarily examined for the purpose of detecting the presence or absence of typhoid organism.

6589 Experiments made with typhoid bacilli inoculated into sterilized water have demonstrated the ability of this organism to live for a period measured by a number of months and in some instances upwards of 100 days. The results obtained are widely discordant with respect to the exact time.

Interpreting your question to refer to the viability of an organism in boiled waters, I am of the opinion that the vitality of the organism might be retained in the water sterilized by boiling, a longer time than would be the case if the organism was

exposed in contact with human dejecta, in a moist condition.

Concentration of the sewage material on the life of a
6590 typhoid germ would not be operative beyond a certain point. The difference between the sewage containing, say, 10 per cent of solid excreta, and say 20 or 25 per cent of solid excreta, would not be such as to materially alter the rate of loss of vitality.

6591 My opinion is that the changes that have been produced in the Chicago river through the opening of the drainage canal, are not such as will greatly modify the death rate of the typhoid organism when exposed under these two conditions.

This opinion is based upon my belief that in either instance the degree of concentration in the water of bacterial by-products, and the presence of saprophytic bacteria themselves would be sufficient to cause an early death of typhoid organisms placed in this water.

(Witness states the typhoid epidemics that he has personally examined and the sources of infection in each case.)

All of these epidemics were caused by sewage pollution.

6595 (Witness is cross-examined as to the experiment on longevity of typhoid bacilli that was made by him.)

6607 ISHAM RANDOLPH, Examined in chief by Mr. Todd: Have been civil engineer since 1868. (Witness gives educational qualifications and experience.) In 1893 was elected chief engineer of the sanitary district of Chicago and have retained that position ever since. My first familiarity with the Chicago river began in 1880 in connection with some work I was doing for the West Indiana Railroad Co.

6609 This brought me in constant visual contact with the Chicago river. It was at that time and remained for many years thereafter a very foul stream, the water black and ill smelling and often covered with a slime, a black slime, and in the summer seasons there was a great deal of agitation of the waters due to gases arising from the putrescent matter in the water.

The Chicago river at that time was a body of water which

sometimes flowed up stream and sometimes down stream. Under ordinary lake conditions there was a very, very slight current to the westward, due to the pumping works at Bridgeport.

When the lake was rising the water came in the river quite rapidly. When the lake was falling the flow was in the opposite direction, towards the lake, and in times of freshest there was a strong flow towards the lake. In times of freshet the Bridgeport pumps had to be suspended, and whenever the flow was towards the lake the foul waters of the river passed out into the waters of Lake Michigan, and when there was a freshet, accumulated filth of the river was swept out into the lake and went out for long distances, and the consequent effect of putting foul water into pure water was to diminish the purity of the water into which it was put.

This condition of the Chicago river which I have described, obtained up to 1900.

6610 (Witness describes the sewage system of Chicago, levels, outfalls, etc.)

6611 (Witness produces a map published in one of the reports of the Commissioner of Public Works of Chicago, showing the location of all sewers of Chicago emptying into Lake Michigan and into the Chicago river, which said map is reproduced on page 6612.)

6613 When Chicago was a young city the surface was so slightly above the level of the lake, it was impossible to put in sewers, the drainage was all in open ditches, and during Mr. Chesborough's administration of the engineering department of the city, he planned a sewage system which required the elevation of the grades of the streets. This street level admitted the putting in of sewers which would have fall enough to produce a flow towards the outlet. That slope is very slight, indeed; in many instances it is as small as half an inch to 100 feet, and I think I recall instances where it is even less than that. The result of this is that there is often an accumulation

of organic matter in the sewers which is flushed out in times of heavy rainfall or melting snows.

At one time it was the habit in the city to flush them mechanically. They had very large square tanks, mounted on trucks, that took from four to six horses to haul them around, and they would stop this tank over a manhole and let down a spout in the man hole, open the valve and empty the water from the tank into the sewer and flush it in that way. They were kept flushed for many years in that way.

The Illinois and Michigan canal was commenced about the year 1836 and completed in 1848. It extends from a junction of the south fork of the south branch of the Chicago river in the city of Chicago and in a southwesterly direction across the divide between the Lake Michigan watershed and the Illinois valley watershed, through to Peru, Illinois, a distance of about, as I remember it, ninety-six (96) miles. This canal had a navigable depth of about 5 feet and a navigable width of about 60 feet. Its locks were 110 feet long and 18 feet wide. What is known as the summit level extends from the south fork of the south branch of the Chicago river, through to Lockport, a distance of about 29 miles. The summit level since 1884, I think it was, has been supplied by pumping works located at Bridgeport in the city of Chicago. The pumps were under a guaranteed capacity of 60,000 cubic feet per minute. Prior to the erection of the pumps of which I have just spoken the summit level was supplied by water coming in through what is known as the Sag valley. There was a dam at Blue Island, draining off the Calumet river and dividing its flow, a portion of it through a shallow channel, dug for the purpose, and conveying it into the Illinois and Lake Michigan canal at Sag bridge. At a period prior to 1870, the date I do not recall, this supply became inadequate and pumps constructed on the principal of the stern wheel to a stern wheel steam boat were put in at Bridgeport, for the purpose of supplying water for this summit level. At some time prior to 1870 the city of Chicago undertook to deepen the summit level and get a gravity

6614

flow from the lake through the canal. This work was in progress at the time of the Chicago fire, and a very large sum of money had been expended by the city, something approximating $1,000,000.00, or a little more, I think, and after the Chicago fire the State of Illinois refunded this expenditure to the city. This gravity flow proved inadequate because the channel had not been made deep enough and pumping works were again established at Bridgeport and the pumps that were put in had a guaranteed capacity of 60,000 cubic feet per minute and lift between 4 and 5 feet. As a matter of fact those pumps did not in practice accomplish what they were claimed to do, and the flow fell to in the neighborhood of 50,00 cubic feet. It ranged between 45,000 and 50,000 cubic feet a minute. This supplied the summit level from Bridgeport to Lockport and the intermediate level between Lockport and the upper pool at Joliet. At Joliet the canal and the Des Plaines river flowed together through the upper pool as far as dam number 1. At dam number 1 there was a lock called lock number 5, which passed the flow from the upper pool to the middle pool. The middle pool was created by the building of dam number 2 at Jefferson street in the city of Joliet. At dam number 2 the river and the canal again separated and the canal had an independent course from that point through to LaSalle, where it emptied into the Illinois river. The supply of what is known as the Chanahan or twelve mile level extending from Joliet to Chanahan was taken from the Des Plaines river at its junction with the waters coming through the canal from the Bridgeport pumping works. At some seasons of the year the supply of water from the Des Plaines was very small indeed,

and the canal was almost wholly dependent for its avail-
6615 ability as a navigable stream upon the waters pumped from Bridgeport.

These pumps were placed at Bridgeport in 1884 and paid for by the city of Chicago. The forebay from which this water was pumped connected directly with the south fork of the south branch or what was known as the stock yards branch. The water entering the pumps came partly from the stock yards

branch and partly through the south branch of the Chicago river from Lake Michigan. There was a certain small flow of water, due to sewage discharged into the stock yards branch which met the flow from the lake, and the two mingled and were drawn into the pumps. The water flowing through the summit levels at a very slow velocity, probably a mile an hour, was a black liquid, with a very foul odor, and would leave a greasy black stain on anything that was put into it. The water in the two pools at Joliet was at some seasons of the year as bad as that in the canal proper, because there was so little dilution coming in from the Des Plaines river, and it was only bettered by what water came in from the Des Plaines river. At some seasons of the year that flow was large, and the conditions were very much improved, but in the dry seasons they were foul, horrible pools.

6616 I have never traversed that stretch of the Illinois and Michigan canal from Joliet to Ottawa by boat. The stretch from Ottawa south I have traversed by boat. At Ottawa I made a careful investigation with the eye and the nose only of conditions, and at that point I could not detect anything whatever by the eye or the nose, which indicated that the water contained sewage. From there on down the conditions were as good as they were at Ottawa and probably improved continually as we went down.

The sanitary and ship canal has been the outcome of Chicago's necessities. The conditions affecting Chicago's drinking water had gotten steadily worse from the days when it begun to be a city. The conditions were such that the public generally was excited and the public men of the city determined to see what could be done to relieve the city.

It reached a period in 1886 that the city council authorized the mayor, the elder Carter H. Harrison, to appoint an expert commission to decide what should be done for the city. That commission was appointed, I think in January, 1886, and Rudolph Hering, then of Philadelphia, was made the engineer in charge. His associates were Benizette Williams and Samuel J. Artingstall. These gentlemen were authorized to employ

expert help, to make surveys and investigations and to prepare a report accompanied by their recommendations. The final report of this commission was never made. The preliminary report I have seen, and in fact there is a copy of it in the report of Major W. L. Marshall, accompanying his report to the governor, I think for the year 1889. In 1889 the sanitary district law was passed, authorizing the formation of drainage districts in the State of Illinois.

6617 Under that law a board of trustees was elected, consisting of nine members, with power to organize, decide upon plans, levy taxes, enter into contracts and prosecute the work as to them seemed best. This board adopted the project for a water way from Chicago to Lockport, this water way to cause a flow of the waters of Lake Michigan through the Chicago river and through the channel which they constructed artificially and discharged in the Des Plaines river at or near Lockport, Will county, Illinois.

The sanitary and ship canal follows the general location of the old Illinois and Michigan canal from Chicago to Lockport. It traverses the territory which is partly tributary to Lake Michigan and partly to the Illinois water shed. It connects with the west fork of the south branch of the Chicago river at Robey street in the city of Chicago; runs in a southwesterly direction through a clay formation and crosses the divide near the "Summitt Range line." The lowest point in the divide between the water shed of the Illinois, the Des Plaines valley and that of Lake Michigan is almost on this summit range line.

Before the building of the "Ogden ditch" the natural surface at its lowest point was 11.72 feet above Chicago datum. Chicago datum is a plane of reference adopted for horizontal elevations by the engineers of the Illinois and Michigan canal when its construction was entered upon. It so happened that this elevation corresponded with the low water of 1847 and hence Chicago's datum is always spoken of as the low water of 1847 in Lake Michigan.

The first seven or eight miles of this channel is through a clay formation a formation which can be readily dredged, and the cross-section of this stretch of the channel is now less than what it is to be ultimately. It is only 110 feet wide on the bottom; the side slopes being 1 foot vertical to 2 feet horizontal, giving a surface width with a minimum depth of water 22 feet, of 198 feet. At the end of this stretch of channel material was encountered which could not be readily dredged. It is described in our specifications as glacial drift. There the full size channel was entered upon. This full size channel is 202 feet wide on the bottom with side slopes as before of 2 feet horizontal to 1 vertical, and the resulting width at the water line is 290 feet with a minimum depth of water 22 feet.

6618 This cross-section of the channel is held for 5.3 miles until Willow Springs is reached; there the rock was encountered. The territory from there on to Lockport is either wholly rock or is underlaid by rock.

The channel contracts at this point to 160 feet in width. The grade is increased from 1 foot in 40,000 feet, which is equivalent to an inch and ⅝ to the mile, to 1 in 20,000 feet.

The length of this cross-section is 14.95 miles. Seven miles of this distance is through cut in rock, the sides are cut practically vertical with two offsets of six inches each on each side, so that the surface width is 162 feet. Wherever the rock did not come to the surface, walls were built from the rock at the elevation found to a height of five feet above Chicago datum.

It was necessary that perfect control of the flow through this channel should be maintained and to accomplish this, controlling works were erected at Lockport. These works consisted of seven lifting gates of the Stoney type, and one bear tray dam. The gates have an opening of 32 feet each. They are counterbalanced and operated by winches, so constructed that two men can raise or lower the gaets under pressure, although each gate weighs 62,000 pounds.

(Witness describes the construction and operation of the Bear Trap dam and also of the bridges across the drainage canal.

6620 Work was begun on the 3d of September, 1892. The water was let into the channel on the 2d day of January 1900. The water flowed over the Bear Trap dam on January 17, 1900.

6621 It took from the 2d of the month to the 14th to fill the channel to the level of Lake Michigan.

6621 The work of executing the plans of the district had gone steadily on. The Chicago river as it was in 1898 did not afford an adequate channel to supply the water which the Sanitary District law required us to flow through our channel. Prior to the beginning of work by the Sanitary District the flow through the Chicago river would have been limited to 150,000 cubic feet and the plans of the sanitary district provided for widening the Chicago river uniformly for 200 feet, deepening it for the central 100 feet to 26 feet below the water surface, making the depth at the dock lines 16 feet. This would give the river a capacity of 480,000 cubic feet per minute, and a velocity not exceeding a mile and a quarter per hour.

The district is also engaged in removing center pier bridges from the river and substituting therefore Bascule bridges. We have completed seven Bascule bridges. We have two now under contract. We have the plans under way for four additional bridges, in fact that are partially completed, and we propose to do away with the center pier bridges in the Chicago river.

The channel of the Des Plaines river south of Lockport

6622 was entirely inadequate to the demands which would be made upon it by the combined flow of the flood waters of the Des Plaines and the discharge from the sanitary and ship canal. It was therefore necessary that the district should deepen and enlarge this channel which it has done to an extent which enables us to carry these combined waters safely through the city of Joliet.

We have made a provision for a flow of 1,500,000 cubic feet of water per minute. For one mile south of the controlling works an entirely new channel was made for the Des Plaines river; that brought us to the precipitate slope of the valley. There instead of making a new channel we bought the lands on each side which would be submerged. This method of caring for the water was adopted as far as the E. J. & E. bridge just north of Joliet. From that point into the upper basin we made an entirely new channel for the Des Plaines. In the upper basin the width of which was 300 feet we deepened the basin to give a sufficient cross-section to carry the water which I have mentioned as 1,500,000 cubic feet per minute. We were compelled by the Illinois and Michigan Canal Commissioners to rebuild dam number 1, which we did. The middle basin we destroyed, tearing out dam number 2 and maintaining navigation in the Illinois and Michigan canal by building a channel for said canal from dam number 1 to the guard lock located at Jefferson street. After tearing out dam number 2, which made the second pool, we widened and deepened the river between Jackson street and Jefferson street. We continued this widening and deepening from Jefferson street through to a point about 800 feet south of the Rock Island bridge. From that point to the mouth of Hickory creek, we built a massive embankment to prevent the over flow of the adjacent territory by the flood waters. We were compelled by the city of Joliet to build new bridges at Cass street and at Jefferson street.

The grade in the channel from Robey street to Lockport falls 5.62.

6623 From Robey street to Lockport the channel is 28.05 miles long and from Robey street to the mouth of the Chicago river is six miles, with a grade of 2 feet. The level of Lake Michigan is variable. The widest fluctuations are caused by wind effects. The fluctuations have amounted to something

over four feet. (Witness gives figures showing the total cost of the canal as being $42,503,168.80.)

6624 The original sanitary district took in all of the city of Chicago north of 87th street except a part of Roger's park and Norwood park, and 42 square miles of the country lying directly west of that portion of the city. Originally this embraced 135 square miles. The work on this canal was done under authority of the act of the legislature of 1889, copy of which act is offered in evidence marked "Defendant's Exhibit, Randolph's Exhibit A."

6625 Under the act of the legislature extending the boundary of the sanitary district, passed last session, 78.6 square miles of territory was annexed on the north side, known as the North Shore district, and on the south side 94.48 square miles was annexed, known as the Calumet district. That completes the taking into the sanitary district of all the city of Chicago. The whole city is now in the sanitary district. I have a map showing the territory of the sanitary district as it was first laid out, and the present territory embraced in the district, which is reproduced on page 6626.

6627 Plans are being made for caring for the annexed district. It is proposed to reverse the flow of the Calumet river by constructing a channel from a connection with the Calumet river near Blue Island. This channel extends southwesterly, through what is known as Sag Valley to a junction with the sanitary and ship canal at or near Sag Station on the Alton railroad. This channel will reverse the flow of the Calumet river and prevent the discharge of its waters into Lake Michigan at all times except in excessive floods. Provision can not be made for taking the entire flood waters of the Calumet region through our channel. On the north, it is proposed to extend the north branch of the Chicago river northward as far as Evanston and make a connection with Lake Michigan at that point, at a point almost on the boundary line between Evanston and Winnetka. The lake level being the same at this point of junction as it is at the mouth of the Chicago river, it will be

impossible to get a gravity flow through this channel, and therefore, pumping works will be erected at the north end, designed to pump 60,000 cubic feet of water per minute into this new channel. Into this channel all the sewage arising along the north shore is to be delivered by sewers constructed for that purpose. The population of the city of Chicago, by the census of 1900 was 1,698.575. Making up the population curve, based upon past experience and future probability, we bring that population down to 1903, as 1,878,000 at the end of the year.

6628 The total population of the sanitary district is 1,942,000.

The general plan of the district for providing a means of carrying off the sewage has been described. The city in conjunction with the sanitary district is at work with a system of intercepting sewers both from the north and the south side. The city has built a conduit in 39th street, 20 feet in diameter, and having a capacity of 120,000 cubic feet of water per minute. At the lake end of this conduit a pumping station has been established in which there are to be six pumps. Four of these are put in by the city for pumping sewage from the intercepting sewers, sewage mingled with lake water. The combined capacity of the four pumps is 40,000 cubic feet a minute. The sanitary district puts in two pumps which take their supply direct from the lake without sewage pollution and each of those pumps has a capacity of 40,000 cubic feet per minute. They are the largest pumps ever attempted in the world. On the north side of the city on Lawrence ave., the city is building a conduit to receive the intercepting sewers. That extends from the lake across to the north branch of the Chicago river. The intercepting sewers bring in the sewage from the north and south into these conduits. The pumping station is to be erected at the cost of the city and to be operated by the sanitary district. This pumping station will have a capacity of 35,000 cubic feet of water per minute, with arrangements made for doubling that volume if

it is found necessary, but the pumps will only be put in at present for 35,000 cubic feet per minute.

6629 When the improvements contemplated by the sanitary district for the territory north, and the Calumet river on the south, as well as the system of intercepting sewers and the canal itself in the earth section, and the Chicago river are completed, the maximum capacity of the drainage canal will be about 825,000 cubic feet per minute. I have tables showing the flow of the canal as measured at the Bear Trap dam since its opening, up to the middle of 1903. For 49 weeks in 1900, the average was 188,136 cubic feet per minute. The smallest flow was on the 17th of September, 1900, 1863 cubic feet per minute, and the largest was on the 26th day of the same month, 326,791. In 1900, the dams at Lockport were only closed for a few hours on two or three occasions when vessels got stuck in the channel. I have no knowledge of the water everflowing through to the lake but once since the channel was opened. Once there was a freshet in the north branch—it was a general freshet and it was not watched close enough to take care of it and that flow began to go towards the lake, and as soon as that was noticed, we checked it in a very short time.

6630 That flow towards the lake did not last but a very short time—probably two or three hours. (Witness gives the maximum, mean and average flow through the I. & M. canal for 1900, 1901, 1902 and 1903, as follows:

On March 16th was the largest flow of the year 1901, 406,227 cubic feet per minute. On October 3d was the lowest, 139,427 cubic feet. The average for the year was 242,323.

Now, we will take 1902. For 1902 I find that the lowest flow was on June 3d, when the works were shut down fourteen hours on account of the flood in Joliet, the Hickory creek disaster, 107,231 cubic feet was the lowest. There was some water running all the time but not enough to interfere with the flood

below. The largest flow was on December 26th, 339,610 cubic feet. The average for the year was 257,006 cubic feet.

For the first six months of 1903 it shows the greatest flow to have been on June 5th, 401,425 cubic feet per minute, the lowest May 30th, 248,063 cubic feet, the average 312,692 cubic feet.

The highest record of the Illinois and Michigan canal was on February 8th, 57,677 cubic feet per minute. The lowest when there was anything doing at all—there were a few days when there was nothing doing—was 14,800 cubic feet. The average as 26,768 cubic feet per minute. That is for 1900.

The canal appears to have been shut down entirely from the first of January, 1901, to the 24th of April, 1901. The minimum was on April 24th, 3,840 cubic feet; on July 3d, the maximum was 29,206, and the average for the 26 weeks was 20,073.

In 1902 the pumps were started May 1st. The minimum was 9,200 cubic feet per minute, the maximum 25,080. The pumps were only run for 27 weeks, and the average 22,488.

The first six months of 1903, on January 13th, was the
6631 minimum, 1,913. On June 5th was the maximum, 28,114
the average for the 26 weeks 21,996.

The average per capita consumption of water in Chicago for 1900 was 190 gallons. For 1901, it was 195 gallons and for 1902, it was 197 gallons. As to the Des Plaines river, there were two periods during 1900 when there was no water flowing past.

There were two periods during 1900 when there was no water flowing past Riverside at all. It was simply a pool, from May 31st to June 5th, and from June 26th to July 7th. The largest volume of water passing was on March 19th, 290,350 cubic feet per minute.

For 1901 there was a period from February 11th to March 2d when there was only 2,400 cubic feet of water flowing per minute. About March 30th there was 331,680 flowing, and the average for the year was 20,974.

In 1902 there were several periods in the year when there

was nothing flowing at all past Riverside and the maximum on May 26th was 37,740 cubic feet. The average was 30,235.

The first six months of 1903, the smallest flow was June 19th and 20th, 1,200 cubic feet per minute. The largest was March 21st, 437,520 cubic feet per minute, and the average was 4,307.

The mean average flow of the Des Plaines, the Chicago drainage canal, the Illinois and Michigan canal, at Dam Number 1, where these three waters commingle was as follows:

The mean for 49 weeks in 1900 was 233,976. The mean for 52 weeks in 1901 was 277,153. The mean for 52 weeks in 1902 was 294,132. The mean for 26 weeks in 1903, ending June 27th, was 385,475.

6632 I have prepared a table showing the pollution at dam number 1 based upon the mean discharge from the drainage canal, the I. & M. canal and the Des Plaines river, as well as the population discharging sewage at that time. Said chart is reproduced on page 6633.

6634 (Witness describes table referred to.)

6635 The ratio of sewage to the mean discharge of the drainage canal as evidenced by this table for 1900 is 1 to 9.2; for 1901, 1 to 10.2; for 1902, 1 to 10.4. The proportions of urine and fecal matter to the mean discharge of the canal for 1900 is 1 in 5429; for 1901, 1 in 6211; for 1902, 1 in 6310. The table referred to is number 1, pollution of sanitary canal by the sanitary district.

6636 Table 2, same series.

6639 Table 3, shows population curve of Chicago.

6641 Table 4, shows population of Chicago.

6644 Table 5, is headed "Excreta" and purports to show the amount of excreta from 100,000 persons per year.

6646 Table showing pollution of Illinois river from tributaries.

6648 From the tables which I have introduced, I conclude that the natural pollution of the Illinois river is due to the urban and rural population draining into its watershed, exclu-

sive of all sewage coming from Chicago, is more polluted than the waters of the Illinois river are when combined with the discharge from the sanitary canal after the opening of said canal. In the conditions which obtain without considering the discharge from the sanitary canal the pollution is 1 in 17.48. The pollution, considering the sanitary canal, is 1 in 34.3.

6649 Map showing various watersheds of the Illinois river from Chicago to Grafton and marked "Defendants' Randolph's Exhibit B." (Witness describes the physical characteristics of the Des Plaines river.) Prior to the opening of the drainage canal, the water that went south in the I. & M. canal through the Bridgeport pumping works was in a highly polluted state.

6652 The pumps were installid, that is the set of pumps were put in after the deepening of the canal. The canal was deepened between 1865 and 1871 and the flow was only about 9,000 cubic feet per minute. It was insufficient for the sewage and the pumps were put in the latter part of 1884. The operation was commenced about the end of the year 1884. (Act to provide for the completion of the I. & M. canal, approved February 16, 1865, offered in evidence.) From 1884 to 1900 the average column of sewage pumped from the Chicago river into the I. & M. canal was approximately 50,000 cubic feet per minute.

6653 It flowed through that canal to Lockport where a portion of it was discharged into the Des Plaines river over a waste weir or else passed through the wheels of the water power at that point. What did not enter the river at this point entered it after the Des Plaines river reached what is known

as the upper basin at Joliet. The complete mingling was in the basin at Joliet.

6654 Chart showing urban population on the Mississippi river and its tributaries.

6655 (Witness gives gauge readings asked for by Professor Van Ornum, in a letter, the reply to which was read into evidence.)

6658 Discharge chart showing volume of flow of the upper Mississippi river.

6660 Same for the Missouri river.

6661 Chart showing flood combinations in the Mississippi river at St. Louis, Paducah and Cairo, also giving conditions in the Ohio river and in the lower Mississippi.

6663 Flow measurements at Peoria.

6664 Flow measurements at Kampsville.

6666 Profile of waterway from Lake Michigan to Cairo.

6667 I made an experiment with floats to determine the velocity of flow from Chicago to St. Louis.

6669 Table showing time from Lake street, Chicago, to Eads Bridge, Mississippi river, at St. Louis, the total number of days being 18 1-2.

6670 At the time this experiment was made it was not a flood time nor was it at low water. It was a full river, but not a flood.

6672 Page 11, 17th annual report of the Health Commissioner of St. Louis for 1893 and 1894 read in evidence.

6673 Also page 36 of the same report, being a resolution of the Board of Health of St. Louis to the mayor and municipal assembly requesting them to memoralize Congress concerning this matter and requesting that a suitable commission be appointed to investigate the prospective pollution by sewage from Chicago.

6674 Page 38 of same report read in evidence, being an order that the city chemist collect samples for chemical analyses, also a report by the chemist that samples were collected.

6675 Page 42 of same report read in evidence, being the report of the city chemist, as to the result of his examinations.

6676 Page 43 of same report read in evidence.

6677 Page 45 of same report read in evidence as follows:

Regular meeting, January 8th. The following correspondence between the mayor and health commissioner was submitted to the board. Letter from the mayor, January 6th:

"I have received yours of the 22d with accompanying reports bearing on the subject of the quality of the water of the Mississippi river between the Chain of Rocks and a point five miles above the mouth of the Illinois river as recently determined by the city chemist. Also charts illustrating the results arrived at by a chemical examination.

I have examined these charts and reports as carefully as my want of technical knowledge will permit. The result of the work is undoubtedly presented in a very graphic manner; indeed, it seems to me that a technical knowledge is hardly necessary to understand the results as shown by the reports and charts before me, assuming that the work of the city chemist so far as it went was thorough and reliable. I have no reason to doubt that the city chemist, Teichmann's, work can be depened on as representing the true conditions. It is my understanding that this investigation was the result of a suspicion that our water supply was being contaminated by Chicago sewage coming from the Illinois river.

Briefly, then, I find from the charts before me conditions as follows:

Substances supposed to contaminate drinking water in dangerous quantity in the Illinois river, also spots in the Mississippi river betwen the mouth of the Illinois and the Chain of Rocks and in the mouth of the Missouri river. I find, however, that at Grafton, about 1 mile and a half below the mouth of the Illinois the water is purer than at any other point in the river between Grafton and the Chain of Rocks. That is to say, nothing of the objectionable substances seem to exist in dan-

gerous quantities one mile and a half below the supposed source of contamination while the pollution increases and diminishes below that point at irregular intervals. This, it seems to me, tends to disprove the theory that the contamination (if there be any) at the Chain of Rocks comes from the Illinois river and goes to show that the offensive substances found in spots along the river between the mouth of the Illinois
6678 and Chain of Rocks are due to local causes. The comparative purity of the water at Grafton seems to be inconsistent with the theory that the water below that point is contaminated from the water from the Illinois river. The conditions existing at the mouth of the Missouri river, as shown by the chart, suggests that as a much more probable source of the pollution than the Illinois river.

In view of these conclusions which seem to me necessary upon the facts before me I do not think further superficial investigations would be desirable at this time. In fact, it seems to me the tendency of the work done by our city chemist is to give confidence in the purity of the water supply at the Chain of Rocks, so far as influences are concerned within our control affecting the water at that point and I am, therefore, inclined to think that if further work be done the investigation should be conducted by a commission of thoroughly equipped experts, backed by sufficient appropriation of money to enable them to make an exhaustive and final report. The money at command under your present appropriation seems to me, not sufficient to do more than has already been done by Dr. Teichmann with seeming thoroughness. If sufficient funds can be made available to prosecute further work with thoroughness I shall be glad to co-operate with you to a final settlement of this vexed question."

6679 Page 11, 18th annual report of health commissioner of St. Louis for year ending March 31, 1895, being a report under the head of "Federal Rivers Commission," read in evidence. Various pages of report read in evidence by witness, tending to show that in the year 1895 the question of the pollu-

tion of the St. Louis water supply was under consideration by the St. Louis health authorities.

6682 Robert E. McMath was commissioner of sewers of St. Louis from 1887 to 1891. He delivered an address upon the question of the Illinois river on May 30, 1888 before the Engineers' Club of St. Louis and that address appears in the Journal of the Association of Engineering Society for the year 1898.

6683 (Witness reads from parts of the address above referred to.)

6684 (Witness reads extracts, including the following:) "Sewage in 1886 could not be traced farther than Ottawa. The general result (of the I. & M. canal) is a betterment."

6685 (Witness reads from page 12 of the 17th annual report of the health commissioner of St. Louis for 1893 and 1894 under the heading of Wells, to the effect that a number of wells have been condemned and that notwithstanding the low standard established, very many wells were found to contain water utterly unfit for human consumption.)

6687 Page 204 of report of the health commissioner for 1895 read in evidence, showing 437 public wells and 4,848 private wells in St. Louis.

6688 CROSS-EXAMINATION by Mr. Jeffries.

Since the opening of the canal the water from the various cribs in Lake Michigan is frequently pronounced unsafe by the health department, and citizens using it for domestic purposes are requested to boil it. (Witness is cross-examined as to population drained by certain sewers and generally, on the sewage system of Chicago.)

6700 LUDWIG HEKTOEN, Examined in chief by Mr. Todd: Am physician and surgeon. (Witness states his qualifications as a pathologist, bacteriologist, etc.)

6701 Am professor in pathology in Rush Medical College and also at the University of Illinois.

6702 Am not in the general practice of medicine but am devoting my entire time to investigation. Have been doing the larger share of the post mortems at the county hospital for many years. Have studied germ diseases. Have studied in Sweden, at the University of Upsala, in Prague and Berlin. (Witness describes typhoid fever and its clinical diagnosis, also intermittent, remittent, typho-malarial, congestive and simple continued fevers and states that these latter named fevers are not distinct types of disease and so recognized by pathologists, bacteriologists and clinicians.

6705 As applied to vital statistics, I think that in a large per centage of the cases these fevers mean typhoid fever.

(The number of deaths from typhoid as shown by annual reports of the board of health of St. Louis from 1890 to 1903 and also the number of deaths recorded in same reports under the heading of remittent, etc. fevers read to witness.)

6706 (Witness then states:) The number of deaths reported as occurring from typhoid fever alone in St. Louis do not properly represent in my opinion the total number of typhoid deaths actually occurring in that city, because of the large number of deaths recorded under the heading of remittent, etc. fevers. The number of deaths attributed to the malarial fever, so-called, is in my opinion excessive, and that of course depends upon erroneous diagnosis by the physicians of St. Louis and is undoubtedly the result of the teaching laid down from the early periods where these different forms of disease, especially typhoid fever and malarial fever were not distinguished one from the other.

6707 In my opinion 75 per cent to 90 per cent of those cases under the heading "Remittent, etc. fevers" ought to be put in the typhoid column and from 10 to 25 per cent as malarial fever. The tables appear to show that until the year 1900, when one of these diseases occurred in considerable numbers in a certain month of the year, the other disease occurred to about the same extent at the same time, whereas after 1900 the num-

ber of deaths from remittent and intermittent fevers, etc. is on the whole, smaller than from typhoid fever.

6708 If we add the totals of tables for typhoid fever and the tables for remittent, etc. fevers, the figures thus obtained do not appear to me to show any increase in typhoid fever mortality.

6709 I think the circular letter issued by the health department in 1901 to physicians, manifests itself in these statistics. It would seem to appear in the prominent increase in the number of deaths from typhoid fever, associated with a corresponding prompt decrease in the number of deaths from remittent, intermittent and other fevers.

6710 In my opinion I think that the approximate truth as to the amount of typhoid fever in St. Louis could be arrived at by consolidating the two tables (typhoid deaths and deaths from remittent, etc. fevers) and then perhaps subtract ten per cent. Based upon such a consolidation the results would show that typhoid fever have decreased in the city of St. Louis since 1900. I arrive at that conclusion by studying the figures in the table. They show that up to the year 1895 inclusive, the death rate from typhoid fever appears to be approximately 80 or 90 per cent, whereas after 1896 up to the period 1900 it appears to be between 50 and 55 per cent, and between 1900 and 1903 the death rate is about the same.

6716 PROF. E. G. HASTINGS, examined in chief by Mr. Todd:

Am instructor and investigator in bacteriology. (States educational qualifications.) Assisted Prof. Russell with the experiment conducted with typhoid bacilli at Averyville. (Witness states how experiment was carried out and the methods employed.)

6733 ELIHU B. SPENCER, examined in chief by Mr. Todd:

Am photographer. Am employed by the sanitary district. Took the 39 photographs contained in album being views from the Eads bridge of St. Louis to Henry along the Illinois

river. Said album marked "Defendants' Spencer's Exhibit A."

6735 In April, 1903, took views between Hardin and Henry on the Illinois river. Album consisting of 46 photographs marked "Defendants' Spencer's Exhibit B," offered in evidence. In July, 1903, took photographs of the Illinois river in lower water, which photographs are marked "Defendants' Spencer's Exhibit C," and offered in evidence.

6736 PROF. ERASTUS G. SMITH, examined in chief by Mr. Todd:

Am professor in chemistry at Beloit college. (States educational qualifications.) Have a laboratory of my own, known as the Beloit Sanitary Laboratory. Am bacteriologist. Have given practically all of my available time since about 1885 to the study of sanitary problems, especially water courses.

6738 I have investigated the typhoid fever epidemics at Baraboo, Wisconsin; Ashland, Wisconsin; West Superior, Wisconsin; Menominee, Michigan, and Rock Island, Illinois and have frequently been called in where typhoid fever was alleged to be present. Two of these were, in my opinion, directly attributable to the character of the water supply, namely, the one at Baraboo and the one at Rock Island. In the others, the water supply, in my opinion, was not so directly responsible for the outbreak. The case of Baraboo which occurred in 1902 was caused by a defective pipe which allowed the seepage of sewage to enter the water supply. The epidemic at Lockport was caused by seepage finding its way into the water supply.

6743 In the prosecution of my sanitary work I have had a great deal to do with different systems of filtration. In fact, I have done work upon filter systems of one sort or another at Davenport, to which water company I have acted as consulting chemist for ten or twelve years, with the filter plant at Rock Island, with the filter plant at Ashland, at Independence, Kansas; at Burlington, Kansas; at Cedar Rapids, Iowa; at Beaver Falls, Pennsylvania; at Warren, Ohio; at Brooklyn,

N. Y.; Binghampton, N. Y.; Denver, Colorado; Kankakee, Ill.; Eau Claire, Wis.; Oshkosh, Wis.; West Superior, Wis.; Burlington, Iowa.

My duties were to look after the quality of the water, the conditions of the filters and determine the efficiency of filtration, meaning by that the satisfactory character or otherwise, in which they were doing their work.

6744 I have investigated the systems of filtration at London, Paris, Antwerp, Berlin and Hamburg.

6745 I have carefully read the chemical and bacterial analysis of the water of Lake Michigan, the drainage canal, the Des Plaines, the Illinois, the Mississippi and Missouri rivers, as made by Professors Jordan, Gehrmann, Palmer and Burrill, the same being published in what is known as "Reports of Streams Examinations," published by the sanitary district of Chicago.

6746 I know the Chicago river, the drainage canal, the Des Plaines, the Illinois and the Mississippi from Grafton to St. Louis. I took a trip on a boat and by car from Chicago to the Eads bridge at St. Louis. This trip was made wholly in the day time, that is, on successive days.

6748 (Witness is asked hypothetical question in regard to the experiment made by Dr. Ravold, with 107 barrels of the bacillus prodigiosus, and states:)

6749 In my opinion, that experiment does not possess value as touching the probable longevity of the typhoid bacillus. The longevity of the bacillus prodigiosus is not necessarily a measure of the longevity of the typhoid bacillus, and it does not contribute to the probability that a typhoid bacillus, entering the drainage canal, etc., would find its way through. But on the contrary, it seems to be an improbability that it would.

In the first place the bacillus prodigiosus is known to flourish under ordinary temperature, given the proper food stuff, and I do not know of any evidence contributory to the

knowledge that the typhoid fever organism flourishes and develops in water.

6750 As to the probability that a typhoid bacillus would pass down the canal it seems to me that the experiment first of all does not show that these bacilli were those which were placed in the water, as we have evidence that they are occasionally found, or forms resembling them are found, in our natural waters. Further, upon studying the question it seems to me that if the bacillus prodigiosus had remained in the water for any length of time they would have found them far up the river, but as I understand the results they were not found above Grafton. If they should persist in constantly diminishing numbers it seems to me reasonable to assume that if these organism were those which actually found their way down the river they would have found them in increasing numbers in the samples taken above; but they did not find them until they reached Grafton, although as I understand from this question numbers of samples were taken, e. g., as 432 samples taken at Joliet. But there is no record they were found there.

6751 The colon test is one of the most important tests used in the determination of the sanitary quality of a water supply. I have no knowledge of the longevity of typhoid bacilli in soil only by reading. Such readings show that certain germs have been found in soil sometimes as high as six months. Mr. Frankland, in his "Micro-organisms in Water," records a case where it was observed after 100 days in sterilized natural water and this may be taken as the maximum which I have seen recorded in any experiments.

6752 It would tend to diminish in numbers and disappear after a few days, some records putting it as six or seven days, and some as high as 26 days, which is the highest I have seen recorded, but that would depend upon the quality of the water used. Experiments show they will not live as long in polluted water as in sterilized water. In fact the longest period of life which we have observed in the case of the typhoid bacillus in ex-

perimental work is where they have taken natural water and sterilized it.

6753 I think I suggested the experiment that was conducted by Profs. Jordan, Zeit and Russell, upon the longevity of the typhoid bacillus.

From such a study as I have been able to make of the quality of the waters in the canal and the Des Plaines and the Illinois rivers, and from the study, especially of the work of Prof. Jordan, it is my opinion that the viability or duration of life of the typhoid bacillus must be brief, surviving but two or three days, so far as those experiments show, not extending beyond that. It was recorded in the experiment, that isolated cases were found as late as the ninth day, but out of some 1100 tests, if I recall just right, by Professor Jordan, in only three of those was he able to note the presence of them. All of them were on a single plate, and the same day. It seems that that experiment would tend to show that the duration of life of the typhoid bacillus in the Illinois river must be brief, not more than three days, or so.

6754 The dams in the Illinois river would naturally increase the amount of sedimentation. A high water always tends to increase the amount of sedimentation contained in water, but in the Illinois river we meet with physical surroundings which tend to compensate for this increasing of sediment so that in the high water of the river you will have a heavy sedimentation from overflowing and carrying the water out over the low lands.

6755 When there is sediment, or matters in suspension in a running stream that assists sedimentation of bacteria.

6756 In my opinion that amount of water passing into the drainage canal could not produce a condition of clearness to preclude the possibility of the opportunity of sedimentation. From the Illinois river, as I had occasion to observe it, in my opinion, if there was 800,000 cubic feet of water per minute discharged through the canal, there would be a considerable amount of sediment yet remaining in the waters. Dilu-

tion of a water with a water of better quality, is one of the well recognized factors in the problem of self-purification of streams. It manifests itself in separating objectionable micro-organisms and thus diminishing the liability of the same being taken into animal economy.

6757 A sewage laden water diluted with a water of a better quality is thereby rendered less liable to communicate disease by infection. It is generally accepted by sanitarians that the dilution of sewage diminished the danger from infection, the greater the dilution the more the micro-organisms are separated and the less the liability of the same being taken in by man. In my opinion the addition of the purer water from Lake Michigan to the sewage improves the quality, that is, diminished the danger from the sewage in that the micro-organisms are more separated from each other and also because it gives the river greater area for facilitating the sedimentation of solid matters suspended in the same.

6758 In my opinion Lake Michigan water added to the sewage of Chicago is decidedly beneficial to the sanitary condition of the river from the standpoint of the chemical and bacterial changes taking place because so far as the chemical changes are concerned, and the bacterial changes also, there will be an elimination owing to the process of sedimentation of material carried by the water and therefore the quantity of the water would be improved.

It seems to me evident that the raising of the Illinois river level would make an increased volume of the river which would widen the sedimentation area and that this sedimentation of the river would be decidedly increased by this rise of level, and thus the total sidimentation of the river would be greatly increased; and further, this raising of the level would also increase the total volume carried by the river so that relatively there would be a smaller quantity of the sediment in any given volume of the river. Thus, it works both ways, hastening the processes of sedimentation.

It is my opinion that the physical conditions of the Illinois

river are such as to be well adapted to sedimentation as compared with other rivers with which I am acquainted. In support of this it seems to me that the low shelving banks of the river are such that a slight increase in the volume of the river and thus a raising of the water above its level tends to broaden out the depositing area for the sediment.

6759 Q. From your knowledge of the physical conditions that obtain along the Illinois river as well as your knowledge based upon the study of the results of the analysis as they appear in Streams Examinations on the water both chemical and bacterial of the Illinois river, what effect, if any, does the sewage from Chicago discharged into the drainage canal have upon the waters of the Mississippi as the same passes along the shore of the State of Missouri?

A. In my opinion all the conditions affect the quality of the Illinois river. Its physical surroundings; the study of the chemical analyses, the comparison of the bacterial analyses; the death rate of the typhoid bacillus; the rate of flow of the river, the Illinois river as discharged into the waters of the Mississippi does not affect its quality as it passes along the State of Missouri, in fact the data probably indicate that the Mississippi river is not of as good quality as the Illinois

6760 river itself in its lower reaches.

In my opinion it seems to me quite clear that there is no pollution dangerous to public health from the drainage canal which receives the outfall from the sewers of Chicago which reaches down the Illinois river as far as Grafton.

There are several factors in connection with the river and the study of the agencies at work in the self purification of the stream in my opinion would justify that statement. We have the agencies of dilution of the sewage whereby the sedimentation of the river is augmented for the reasons previously outlined.

We have the experimental work showing the short life probably not exceeding three days of the typhoid bacillus in the waters of the river.

We have the rate of flow of the river showing that the time required for substances to pass from the drainage canal at Chicago to Grafton considerably exceeded the life period of these organisms as revealed by the special experiments upon the typhoid bacillus of this particular river.

We have further the study of the river from a chemical standpoint which shows the purification of the river from that standpoint and we have also the data from the bacteriological investigations all a matter of evidence which show that the waters have purified themselves from the bacterial standpoint. That is, the waters of the Illinois river at Grafton appear from the chemical and bacteriological standpoints as evidenced by these data to be of the quality of other rivers of this section.

To sum up these conclusions, in my opinion, the several agencies at work make the Illinois river at Grafton about a normal river water in this section.

6761 It is my opinion that infectious matters coming from the sewers of Chicago by way of the drainage canal do not reach as far down the river as Grafton, for the reasons I have outlined in my answer previously given. It is my opinion that the low water in the Missouri river at a time when there was high water in the Illinois, would not be a factor in carrying infected and polluted matters from the sewers of Chicago to St. Louis, because the waters of the Illinois river have become purified through the process of self purification and removed the infected and polluted matters and therefore, the condition of the Missouri river does not enter into the discussion.

6762 For the reasons given above, the agencies which are at work in the Illinois river tending to the self purification of the stream and the removal of sewage material as such from the river it is my opinion that the sewage from Chicago does not affect the water supply of the city of St. Louis or the waters

of the Mississippi river as they pass along the State of Missouri.

6763 From the experiments all a matter of evidence it is my opinion that the typhoid bacilli passing from the sewers of Chicago into the Chicago river, thence into the drainage canal are destroyed in a short period, not exceeding more than 3 or 4 days after passage into the Des Plaines and Illinois rivers.

6764 In my opinion the typhoid bacillus would live longer in the sediment of a polluted stream than it would in the water of the same stream. The time that the typhoid bacillus will live in moist soil does not furnish any criterion for its longevity in the sediment of a running stream; the two conditions are not comparable.

6765 I do not know of any demonstration of typhoid fever germs having lived for a period of one year in the sediment of a running stream. In my opinion, the typhoid fever germ would not remain in the sediment of a running stream for that length of time. The agencies of removal would be at work on the destruction of the germ for the reasons stated.

6766 It is my opinion from all the knowledge that I possess from a study of the analytical data and the conditions surrounding the river that typhoid bacilli coming from the sewage of Chicago and entering the drainage canal could not traverse that distance and survive. This being true, they could not possibly be a danger and a menace to the inhabitants of the State of Missouri using the waters of the Mississippi for drinking and domestic purposes.

The sewage of Chicago, in my judgment, being eliminated from the stream owing to the processes of self purification before the Illinois river reaches Grafton, the matter of the settling basins at St. Louis does not enter into the problem of the puri-

fication or non-purification of the sewage of Chicago, if not reaching that point as undecomposed sewage.

6767 The fact that a settling basin holds a sufficient amount of water to supply for a period of thirty days, with a constant inflow and outflow of the water as this question supposes, is no evidence that the typhoid bacillus will survive thirty days. It is a well known fact in the study of purification of waters by means of sedimentation that the water must be rendered perfectly quiescent. It must not receive inflow waters in order that the maximum amount of purification may take place. Now, that being true it can not be assumed that the period of life of this organism is thirty days, somply because the basin holds that amount.

I have studied carefully the typhoid statistics of the Illinois, Missouri and Mississippi watersheds, as compiled in the table made up from the certificates of the Board of Health of the different cities lying on the three watersheds, which table has been heretofore introduced in evidence. In the matter of the interpretation of mortality statistics, I always have used the number per thousand or the number per hundred thousand. That is an accurate, specific method of determining the rate for any particular city and can be compared with those from any other city.

6768 The mortality percentage basis might be misleading in its conclusion because, for example, you may have a city of 100,000 people and one year there might be 500 deaths, year after year from typhoid fever, but the deaths in one year from all causes might greatly exceed those of any other year, for all causes, so that upon the percentage basis you would have a shifting result, whereas, if you used the number per 1,000, you would have a constant result and thus make the results which would be strictly comparable. The liability of pollution and infection of the river from the rural population is very decided. The relation of the rural population is one of the important questions to be considered always in making up our studies of the epidemics of typhoid fever in any given locality.

Infection from rural population is a very common cause of epidemics. In the case of the epidemic at Plymouth, Penna., Butler, Penna., and Ithaca, New York, the sources of epidemic were traced to pollution from the rural population. Then, in my own experience, I am sure that the prevalence of typhoid in Denver is due to conditions outside of the city, either up the Platte river or up Bear Creek Canon. (Witness states position which the sciences of bacteriology and chemistry occupy in regard to the ascertainment of the purity of river waters.)

6772 In studying the tables of analyses submitted in evidence, it is my opinion that the waters of the Illinois river begin to show a very decided purification at Ottawa, which increases and reaches its maximum at Averyville, which is above the city of Peoria. It receives, at Peoria, and at Pekin, a considerable addition of eswage material; another area, or a zone of purification commences at this point, some distance 30 miles or so below, and is practically completed at Grafton, the river at that point appearing to be water of the quality of rivers of this section. In my opinion it is necessary for a man to have a pretty thorough, working, practical knowledge of chemistry and bacteriology in order to qualify as a sanitary expert.

6773 From all the knowledge available, from the standpoint of chemical and bacterial knowledge, it would be my opinion that a typhoid bacillus, lying in the sediment of a polluted stream, for a period of over 60 days would not be able to cause typhoid fever; for reasons which I have indicated earlier in my examination, it would probably be destroyed in the sediment. In my opinion, polluted and infected matter coming from the sewage of Chicago through the drainage canal, would have become harmless before reaching Peoria and would have been altered so that it would not be deposited on the bottom as sediment as infectious material. The bacteriological data already submitted in evidence, in my opinion and judg-

ment, show the purification of the stream before reaching Peoria.

6774 The chemical and bacterial data already a matter of evidence in this case, showing that the waters have become practically purified before reaching Peoria, it would be my opinion that sewage from the city of Chicago could not be a menace to the inhabitants of the State of Missouri and the citizens of the city of St. Louis using the Mississippi river water.

By comparison of the data submitted by Professors Long, Palmer, Burrill and Jordan, it is my opinion that the Illinois river at Grafton discloses the least amount of impurity or pollution of the three rivers, the Illinois, Mississippi or the Missouri.

It would be evident that if the Illinois river is of a better quality or does not show as much impurity as either of the other rivers, it would really benefit them, if anything, and in proportion as the waters became mixed. If the evidence should be that the Illinois river practically hugs the east shore and does not mix, particularly it would not affect them. If, on the other hand, the data should show that there is a gradual mixing then in proportion as this mixing occurred to that degree it would improve, if anything. The differences are not very great, however, between the data as I have examined them.

6775 I have made surveys of the water of the Mississippi river in passing upon the quality of that water for drinking and domestic purposes, the same extending over a period of at least 12 years. (Witness states different points along the river at which these examinations were made and the results obtained.) (It is important that this evidence be reviewed, as it shows the condition of the Mississippi river from St. Paul down.)

6783 From examinations of the Mississippi river water made at different times throughout a series of years, and at different points reaching from Brainard, Minnesota, as far down the river as Muscatine, it is my opinion that the Missis-

sippi river water in its raw and untreated condition is unfit for use as a public water supply, without treatment, and it is my opinion, therefore, that the mixing of the Illinois river with the Mississippi river water, after it may have received the Missouri river, does not create any added danger to the inhabitants of St. Louis and to the people of Missouri, for public and domestic purposes.

6784 From all my knowledge of conditions that obtain along the Illinois river, from the inspection of the river throughout its entire length, from a study of the analytical data, both chemical and bacteriological, already a matter of evidence in this case, from the rate of flow of the river, from the data adduced regarding the duration of life of the pathogenic germs the same not living more than three or four days in the waters of the stream, with the processes of self purification at work, notably the process of dilution and sedimentation, and the chemical and bacterial changes shown, it is my opinion that infected matter and pathogenic germs coming into the drainage canal from the sewers of Chicago would not reach as far down the Illinois river as the city of Peoria.

6785 In view of all the knowledge which I possess upon the Illinois river, and the study of its physical characteristics, from the study of the chemical and bacteriological analyses of the river already a matter of evidence in this case, from the rate of flow of the river and the duration of life of the typhoid bacillus, the same not extending over a period of three or four days, as already a matter of evidence, from the analytical and self purification operative in the river, notably those of dilution, sedimentation and the bacterial and chemical changes which the river undergoes, it is my opinion that the sewage of the city of Chicago, entering the drainage canal, and thence discharged into the Illinois which in turn empties into the Mississippi river does not constitute a menace and a danger to the inhabitants of the State of Missouri, or to the citizens of the city of St. Louis taking their water supply from the Mississippi river.

I know of no instance on record or in literature on the sub-

ject where a typhoid bacillus has lived for a period of from one to three years in the sediment of a polluted stream or in the water of the same, but on the contrary, the records of all the experiments which I have been able to read, and from all information I have been able to gather upon the subject of the duration of the life of a typhoid germ in a polluted water, is that it is brief, being limited to that of a few days, six or seven perhaps, at the outside.

6787 The effect of increasing water at flood tide from the tributaries of the Illinois river, as well as the Illinois river itself, coming in at points below the entrance of the polluted waters of the drainage canal would and do cause, as I have observed personally, a large area of land to be overflowed along the Illinois river valley, and the effect of this overflow is to greatly increase the area of sedimentation so that the sewage from the city of Chicago entering the river through the drainage canal would have an opportunity for more complete sedimentation; this overflow forms an important factor in estimating the significance to be attached to the element of sedimentation in the purification from the sewage in the stream. It is my opinion that if the volume of water be increased overflowing this greater area of territory, the waters discharging out, becoming retarded in their course, and giving opportunity thus for the sedimentation, it would follow that the sedimentation would be greater when the volume of water was sufficiently large to cause the overflow of a considerable section of

6788 territory adjacent to the Illinois river through the valley.

From all knowledge which I have been able to gather concerning the conditions which obtain in the Illinois river, from my personal inspection of the river, from the chemical and bacteriological tables already a matter of evidence in this case, from the facts concerning the duration of life of the typhoid bacillus, from the rate of flow of the river from the agencies of sedimentation and dilution and the chemical and bacteriological changes which obtain in the river, it is clearly my

opinion that the removal of the four dams namely the dam at Henry, at Copperas creek, at La Grange and at Kampsville would not create a condition which would permit of the sewage coming from Chicago through the drainage canal into the Mississippi river to reach the intake of the waterworks at the city of St. Louis in the Mississippi river and thereby constitute a menace to the health of the citizens of St. Louis and the inhabitants of the State of Missouri, using the water for drinking and domestic purposes.

It is my opinion that prior to January, 1900, the water of the Mississippi river at the Chain of Rocks was not safe and potable drinking water. (Same as to the Missouri and Illinois rivers.)

6790 From my study of the conditions of the river, especially from the study of the chemical analyses of the supply of water, and also the bacteriological conditions of the water of the river as disclosed by such analyses from before and after the opening of the drainage canal, I am of the opinion that the sanitary condition of the Illinois river water has not been materially changed by the opening of the canal.

I have acted as chemist for the American Water Works Company operating the public water plant at the city of Omaha, and also for the Water Company at Council Bluffs, Iowa, across the river from Omaha, both cities taking their water from the Missouri river.

6791 I am of the opinion that the sewage discharged through the drainage canal, has no material effect upon the waters of the Mississippi and the Missouri rivers at the Chain of Rocks. Such changes as it does effect are those due to the mineral salts carried on by the river, as chlorides and nitrates. It is my opinion that the sewage as such, does not reach the mouth of the Illinois river in an unchanged condition.

The waters of the Mississippi after receiving the waters of the Missouri are unsuitable to be used by the citizens of St. Louis for a water supply, in its raw state. I am of the opinion that the present treatment of the water by the settling basins

merely, does not render the same a safe and suitable water for domestic and drinking purposes, to be used by the citizens of St. Louis.

6792 In my opinion, in order to render the waters of the Mississippi river safe after they have received the waters of the Illinois river, at Grafton, and the Missouri river, at its mouth, the same passing down by the Chain of Rocks, the proper method to treat that water would be by some process of efficient filtration.

6794 From my knowledge of the Mississippi river as based upon personal investigations and chemical and bacteriological examinations of the same, and from my study of the analyses of the Illinois river at Grafton, before the waters of the same are discharged into the Mississippi river water I am very clearly of the opinion that the cost of purification of water below the mouth of the Illinois river would not be increased, owing to the waters of the drainage canal finding access to the river, and therefore the cost of installation and operation of a filter plant at the city of St. Louis would not be increased owing to the admission of waters from the drainage canal.

6795 From my knowledge of the quality of the Mississippi river water and the difficulties met with in successfully filtering the same; from personal studies upon filter plants and upon the river; the water of the Illinois river at Grafton being so similar to the waters of the Mississippi river; the waters of the Illinois river at Grafton being, in my opinion, essentiolly the same as they were before the waters from the sewage of Chicago were delivered from the drainage canal into the Illinois river, I am clearly of the opinion that the role which the drainage canal plays in the Illinois river would not affect the cost of installation, management or operation of a filter plant filtering the waters of the Mississippi river at St. Louis after

the same have received the Illinois river at Grafton and the Missouri at a point below.

6796 The same general character as the Mississippi river water, I am clearly of the opinion that it would not cost any more to operate a filter plant or require more skill and expensive managemnet of the same after the sewage of the city of Chicago had passed through the drainage canal into the Illinois river and thence into the Mississippi river water above St. Louis than before the drainage canal was opened.

I have prepared a table of averages based upon the analytical data presented in evidence in this case by Professors Jordan, Long and Palmer, from various points along the Illinois river, the Missouri river and the Mississippi river, which table is reproduced on page 6798. (Witness explains the terms used in table.)

6801 With this explanation of the terms employed in the original determinations and their significance, it is of value to note in this table of results which we have, showing the averages of analyses taken from the Des Plaines, at Joliet, from the Illinois river, at La Salle, Averyville, Wesley, Beardstown and at Grafton, from the Missouri at West Alton, from the Mississippi at Grafton, from the Mississippi at Alton, 100 feet from shore, and from the intake at St. Louis, a very high pollution from sewagic matters in the waters of the Des Plaines at Joliet, the same gradually diminishing as we pass down the river as far as Averyville, showing an increased pollution at Wesley and again diminishing gradually until Grafton is reached.

6802 at the mouth of the Illinois river.

While the data as given by the different men for the periods indicated, namely, Palmer for June, July, August and September, for the years 1899 and 1900, and Jordan for the months of May and June, 1899 and 1900, and Long during the summer months of 1899 and 1900, are not strictly comparable, yet in no essential point do they differ the conclusions which can be drawn from any one of these observers pointing clearly to the chemical purification of the waters of the Illinois river

by the time they have reached Grafton, as indicated by a diminution in the amounts of free ammonia, in the amounts of albuminoid ammonia, the notable increase in nitrates, the diminution in oxygen consumed and in the diminution in the amounts of chlorine.

Another important fact is that the results of 1900 as compared with those of 1899 show at Grafton a diminution in the amounts of free ammonia, a diminution in the amounts of albuminoid ammonia, a diminution in the amount of nitrogen as nitrites, but an increase in the amount of nitrogen as nitrates, a diminution in the amount of oxygen consumed and the chlorine showing an increase by Jordan, a decrease by Long and a very slight increase by Palmer.

In a word the important fact brought out is that the waters have undergone a practical degree of purification when they reach Grafton, and the analytical data clearly show that the water in 1900 was of a quality superior to that in 1899, for these dates given.

Applying the same principle to the averages of the results of waters taken from the Mississippi river at Grafton, it is my opinion that the waters of the Illinois river at Grafton, as they empty into the Mississippi river, are better than the waters of the Mississippi river taken from the river at a point above Grafton.

Applying the same principles of interpretation of the analyses, it is my opinion that the waters of the Illinois, as delivered into the Mississippi river at Grafton, are of a quality, upon these dates for which these averages are given, and they were the only dates from which data were available, which covered similar periods and similar seasonable fluctuations of the stream, and comparing these data the waters of the Illinois as delivered into the Mississippi at Grafton, are upon the whole a better water, chemically, for drinking and domestic purposes than the samples taken from the intake at St. Louis, the water of the intake of St. Louis being the waters of

6803

the Mississippi river after it has received the flow from the Illinois and the Missouri rivers.

I have studied the bacterial tables as submitted by Prof. Jordan and Prof. Burrill and have made a tabulation of results as given by them in their tables, which is already a matter of evidence. (Table read in evidence on page 6804.)

6806 These tables show the following average for four months in the beginning of 1900: Illinois river, at Morris, Ill., 609,125; at Averyville, 75,735; at Grafton, 29,375. Mississippi river at Grafton, 44,187.

From a study of these tables, these tables being the results of the investigations of the samples of water on these different dates of the Illinois river at Grafton and the Mississippi river water at Grafton, I am of the opinion that so far as numbers of bacteria are concerned, the waters of the Illinois river at Grafton are of a better quality than the waters of the Mississippi river at Grafton. I have made a table of averages of bacterial counts from the reports of Prof. Jordan in Streams Examinations. This table gives the averages in the Illinois river and its tributaries and also the Mississippi river.

6807 As the results of such analysis I find that the average number of bacteria in the water of the Illinois at Grafton is a little above that of the average of these streams, namely the Des Plaines river at Lockport, the Kankakee at Wilmington, the Big Vermilion at La Salle and the Sangamon at Chandlerville, and the Fox at Ottawa.

6808 It is to be noted that two of these rivers, the Fox river at Ottawa and the Sangamon at Chandlerville, carry a number of bacteria in excess of that of the river at Grafton. The Illinois river at Grafton is 29,376, the average of the Mississippi river at Grafton, for the same date, being 44,187. The waters of the Mississippi river are not included in this average. It is my opinion, therefore, that the bacterial condition of the water of the Illinois river at Grafton, from such studies as this, is fairly comparable with the waters emptying into the stream at this season through the same period. It is better bacterially

than the average of the waters of the Mississippi river taken at Grafton through this same period.

I have made a table showing comparison of the bacterial flow of the Illinois river at Grafton, with the flow of the Mississippi river at the same place and points below as given in the tables submitted by Prof. Jordan in the report of streams examination. Average of the amounts for the first four months of 1900 when in the worst condition.

6809 Illinois river at Grafton, 29,375 per c.c.

Mississippi river at Grafton, 44,187 per c.c.

Mississippi river at Alton 100 feet from Illinois shore, 43,906 per c.c.

Mississippi river at Alton one-fourth distance from Illinois shore, 69,919 per c.c.

Mississippi river at Alton, mid-stream, 78,044 per c.c.

Mississippi river at Alton one-fourth distance from the Missouri shore, 82,294 per c.c.

Mississippi river at Alton, 100 feet from Missouri shore, 64,233 per c.c.

Mississippi river at Chain of Rocks, 400 feet from Illinois shore, 53,100 per c.c.

Mississippi river at Chain of Rocks, midstream, 69,825 per c.c.

Mississippi river at Chain of Rocks, inlet tower, 58,309 per c.c.

Mississippi river at Chain of Rocks, 400 feet from the Missouri shore, 73,791 per c.c.

Missouri river at Fort Bellefontaine, West Alton, Mo., 56,035 per c.c.

From the results shown by this table, it is my opinion that the Illinois river is better in the number of bacteria contained in the same, than the Mississippi or Missouri rivers at any of the points named in said table. Taking everything into consideration and including all of the agencies of purification, sedimentation, etc., I am of the opinion that the combination of these agencies all tend to practically purify the Illinois

diluted the water, tending on the one hand to push the sewage from La Salle, Morris, Marseilles, Ottawa and Joliet
6834 somewhat further down the river, and also to dilute the same, yet from all data which I have been able to gather in this case from the experiments made, I am of the opinion that the river at Averyville, above Peoria, has undergone a practical bacterial purification. It would be impossible to to say that no germs from any of these points have never or would never find their way into the river at a point above Averyville, but the data at hand upon the purification of the stream make it, in my opinion, quite certain that there are very few pathogenic germs from any point in the river at that point.
6835 Assuming that typhoid fever germs in a virulent condition came from the sewers of the cities mentioned and found their way in such virulent condition to the lake at a point immediately above Peoria in 1892, it is my opinion that the conditions which have obtained since the opening of the canal have been such that it would not make it less liable for them to reach that point than they did in 1892.

Assuming that in 1892 typhoid germs from the sewers at these points mentioned found their way into and were present in the waters above Peoria, the addition of the larger volume of water increasing the speed of the river and dilution of the same would tend to make them more liable to be found from the same points in the stream.

Assuming that disease producing germs were in the Illinois river above Peoria before the canal was opened, of which we have no positive evidnece, it would be true, in my judgment, that the opening of the drainage canal, increasing the speed of the river and the dilution of the same, would render it more liable for them to be there.

6837 The effect of establishing a current in the Illinois river on pathogenic bacteria, assuming that there were pathogenic bacteria in the water, must manifestly be to push such bacteria somewhat farther down the stream.

It would increase their longevity only so far as they might

have been pushed further in the short distance which they might have advanced, owing to the increased speed of the current further, in my judgment it would not affect the virulence of the germ.

In the increase in the speed of the current of a river or stream, the speed of the current alone being brought into consideration, the rate of sedimentation would be diminished. On the other hand if the speed of this current be due to an increased volume of water admitted from Lake Michigan, after the opening of the drainage canal, there would be decided compensation in the loss from sedimentation from the rate of the stream owing to the added area of the waters spreading out over the bottoms by the low shelving banks in the course of the stream so that in my judgment there would not be any very great difference between the total sedimentation in the stream before and after the opening of the drainage canal.

In the bed of stream the increase of the flow of the current would tend to diminish the rate of sedimentation.

6838 If there were pathogenic bacteria in the Illinois river above Peoria, when I examined same in 1892, it would be my opinion from the conditions noted, in the light of knowledge obtained regarding the action of saprophytic bacteria since that time, that the tendency would be to destroy the typhoid and pathogenic bacteria rapidly at that time, as they would have been subjected to the germicidal effects of the water.

6839 From my knowledge of the river and from data and all knowledge which I have been able to gather from the Illinois river and its characteristics it is my opinion that the agencies tending to destroy bacteria were ample in 1903, and I believe they were as ample to affect the changes in 1892. The current may have been more sluggish at this particular time, but in my opinion the agencies were as effective now as

they were then, removing as I believe they do practically the pathogenic bacteria from the stream now.

6842 The numbers of bacteria in waters are important as showing general conditions in a stream; but it is also true that the character of the bacteria, the species of bacteria and especially whether any of the bacteria present are of so-called sewagic types, is of great importance in fixing the sanitary character of any given water. If the analysis shall

6843 show the presence of the so-called colon forms, especially in water, it becomes a matter of considerable importance to determine from whence they come, and in the study of supplies I have carried that out, particular attention has been given to that phase of the study to determine, if possible, the origin of these colon forms or sewagic forms. I am acquainted with the epidemic that occurred recently in the city of Butler, Penna. I was asked by the management of the Beaver Valley Water Company to advise with them regarding the operation of their plant and I was at Beaver Falls several times rendering services to them. Beaver Falls is 60 or 70 miles from Butler. Knowing the conditions at Butler and knowing

6845 it was tributary to the Beaver river, at a comparatively short distance above, I advised the management of the company to be careful in their operation of the plant during the prevalence of the epidemic and the lack of care and disinfecting of the excreta from the typhoid fever patients, and advised that the plant be operated with very great care during this period, and I understand from letters that they followed that advice.

6846 I knew from data at hand and private advices and general knowledge that this river was being polluted at this time, and therefore, I cautioned them to be careful in the operation of the plant. I cautioned them, as I should every one, to use due precautions at all times and especially when there was any reason to suspect that any trouble might arise from special conditions of the river.

JACOB A. HARMAN, examined in chief by Mr. Todd:

Reside at Peoria and am civil engineer. Have been since 1887. (States educational qualifications.)

6847 For the last five years I have been consulting engineer to the State Board of Health of Illinois. (Gives a general description of the Illinois valled, the territory which is drained by the Illinois river, stating the character of the territory drained and to what interests it is devoted, etc.)

6850 The entire drainage area of the Illinois river is devoted extensively to agriculture and pasturage. Stock raising is one of the chief pursuits of the rural inhabitants of this territory. A very large urban population also exists upon this territory, the principal cities being Peoria, Springfield, Pekin, Bloomington, Decatur, La Salle and Joliet. All of these cities are extensive manufacturing points. I have prepared a table of population on the Illinois river drainage basin as part of my report to the State Board of Health, published in the sanitary investigation of the Illinois river, and its tributaries in 1901, page 119, said table being reproduced on page 6851 of this record.

6852 The classification of urban population and rural population is taken upon the basis of that people living in cities and villages of 1,000 or more are included in the urban population and all others are included in the rural population. This classification has been made for the reason that villages of less than 1000 population seldom have any public water supply or public sewerage system and the villages and cities of more than 1,000 population generally have public water supplies and many of them have public sewerage systems.

I have made an investigation of the rainfall for the 11 years of 1890 to 1900, inclusive, using the weather bureau published reports of rainfall as published by the Weather Bureau of the United States. These rainfall records have been compiled for each of the drainage basins of the Illinois river, as described in my testimony regarding the subdivision of the population of the Illinois river basin. My investigation in-

cludes the average rainfall by months and for each year during that period of time.

6853 This in tabular form is published, page 159, of the "Sanitary Investigations of the Illinois River and its Tributaries, 1901," by the Illinois State Board of Health, and is also reproduced on page 6853 of record.

6854 The rainfall data which has gone in evidence is the annual amounts and averages. This rain comes at intervals and frequently raises the rivers to extreme height and especially in the spring when the snow is going off the ground, and the ground is frozen, the decaying vegetable and other organic matter, especially from the pastures, barn yards, etc., is washed off into the smaller streams and then finds its way into the Illinois river producing a pollution of the stream making it muddy and dirty during flood periods.

The discharge measurements were made at Peoria on the Illinois river. The cross-section was taken at the P. & P. U. R. R. bridge, which is the bridge farthest down the stream at the city of Peoria. At that point the railroad embankments are filled to the bridge abutments so that the entire flow of the river must pass between the piers of the bridge. A cross-section of the river was taken at this place and the velocity of the stream was measured by a current meter and from these measurements of the cross-section and the velocity of flow the discharge of the Illinois river was computed. I also have the gauge readings of the Illinois river at that point covering the period 1890 to 1903, inclusive. I have prepared a table of annual discharges at Peoria, covering the years 1890 to 1903, inclusive, which is reproduced on page 6856 of record.

6857 Table showing discharge of Illinois river at Peoria, computed from current meter observations and cross-sections.

6858 Table of discharges for stages of the river from one foot to 22 feet by tenths of a foot. This table is also published in the State Board of Health report, page 176.

6859 Discharge diagram.

6861 Table of discharges of the Illinois river as affected by its tributaries, based on discharge measurements at Peoria.

6863 On March 10th and 11th, 1903, I made an investigation of the sewage system of St. Charles, Missouri. All the sewers of the city drain into the Missouri river. The city is located upon the left bank of the Missouri river above where it empties into the Mississippi river. The distance overland from St. Charles to the business district of St. Louis is about 16 miles. The drainage of the business district and of nearly all the residence district flows direct into the Missouri river. The drainage of the remainder of the residence district is north to the Mississippi river, which is only 6 miles away. The streets run parallel with, and at right angles to, the Missouri river. The business is done on the first two streets, parallel with and near the Missouri river. The population of St. Charles, in 1890 was 6,161, and in 1900 it was 7,982, from the United States census reports. There is a public hospital which can accommodate about 20 patients located four blocks from the river, which has a sewer on Clay street.

6854 The sewage of St. Louis is discharged by means of main sewers into the Mississippi river. The garbage and cleanings of the streets are disposed of by dumping into the Mississippi river by city dump boats, stationed at various places along the river. Protograph on page 1 of "Defendants' Spencer's Exhibit C," correctly represents the manner of the disposal of garbage in St. Louis.

6865 (Letter read in evidence addressed to James P. Kirkwood, chief engineer, from the office of the Board of Water Commissioners of St. Louis, dated December 11, 1865. Said letter reciting the fact that at a meeting of the Water Commissioners of St. Louis, held December 11, 1865, a resolution was passed to the effect that said Kirkwood proceed at once to Europe and there inform himself in regard to the best

river so that sewage, as such, does not reach down that river as far as Grafton, and, further,

6811 If for the above reasons in my opinion the contamination and the pollution from the sewers of Chicago do not obtain in the Illinois river at Grafton, such contamination and pollution cannot be manifest and present from the Illinois river at the Chain of Rocks in the Mississippi river. I was employed by the Peoria Water Co., at the time of the installation of their new plant in 1892 and I made some analyses of the Illinois river and some investigation as to its sanitary condition at that time. In the course of the investigation made at that time the river was, in my opinion, unfit for use as a public water supply, and at my advice the company dropped the consideration of the stream for that use. In my opinion the water at the present time is of a better quality than it was at that time, in 1892. In the course of those investigations I was upon the river in a boat and went out to and was across the wagon bridge observing the river from time to time, and samples were taken for chemical analysis from the river. It was of a dirty appearance, as I recall it, and possessed, in warm seasons, a decidedly disagreeable odor. The last time I observed the river at Peoria was in September, 1903.

6812 At the time I was there in September there had been a rain storm just preceding it, and the river was muddy and so much silt in it I do not think I could institute a comparison, further than that at the time I was there in September it was muddy from previous rains. There was no odor observable, in September, nor was the water offensive to sight or smell, beyond the presence of the mud and silt in the stream.

6813 I am of the opinion that the water supply of St. Louis is not contaminated, polluted or injured by the sewage of Chicago entering the drainage canal and thence into the Illinois river.

My examination of all data which I have been able to gather together, which bears upon this case, from a study of the tables submitted by witnesses for the defense in this case, from

my knowledge of the conditions of the Illinois river throughout its entire length, derived from the personal inspection of the same, from the data regarding the viability of the typhoid germ and the period of time necessary for water to flow from Chicago to St. Louis, and from my study of the agencies operative in the sanitary purification of this stream, from the chemical and bacteriological changes which obtain through the course of its flow, it is my opinion that sewage from the city of Chicago becomes practically purified at Grafton and the quality of the Illinois is fairly comparable with that of streams forming its tributaries, and that the sewage of Chicago has become purified practically, the pathogenic bacteria having been eliminated in the process of flow of the stream, and hence the original organic matter of the sewage from Chicago does not find its way into the intake tower of the St. Louis water works at the Chain of Rocks.

6814 From studies which I have made upon the question as to self purification of running streams, I am very clearly of the opinion that running water can and does purify itself so as to be free from pathogenic bacteria, which may have been placed therein. From all the knowledge which I have upon the sanitary quality of the Mississippi river after the same has received the waters of the Illinois river, from the fact that the agencies of self purification of a running stream obtains in the Illinois river, from the fact that, in my opinion, the waters of the Mississippi river are not of as good a quality as those of the Illinois river before the Illinois river may have found access to the same, because my study of the Illinois river leads me to consider that the sewage, as a factor has been practically eliminated from the Illinois river before it empties into the Mississippi river at Grafton, I am of the opinion that the Mississippi river at the intake tower of the St. Louis waterworks at the Chain of Rocks is not less valuable for drinking purposes and it is not more liable to carry water borne diseases, such as

typhoid fever and cholera now than it was before the sewage of the sanitary district was run into it.

6815 In my opinion the increase in the speed of the current in the Illinois river would have an effect to remove the sewage from Joliet, Peoria and other towns on the Illinois river, further down the stream, towards the waters of the Mississippi river and this as compared with conditions which existed before this volume of water was added to the river would be to cause sewage to extend over wider reaches of the river.

6816 If the volume of water in the Illinois be increased by the addition of pure Lake Michigan water to the drainage canal, and the speed of the current of the river thus be increased, such increase in said current, in my opinion, would not have any effect on increasing or diminishing the liability to typhoid and other water born diseases on the part of the inhabitants of the State of Missouri using the waters of the Mississippi for drinking purposes, below the mouth of the Illinois river; and for this reason in my opinion from all

6817 studies in regard to the assumption that typhoid germs could pass from the sewers of Chicago, by way of the drainage canal to Lake Peoria and be deposited there in the bed of Lake Peoria for a period of a month it is my opinion from my study regarding the purification of the stream, basing that knowledge upon the analytical data submitted as evidence in this case, which data indicate the removal of sewagic bacteria before Lake Peoria is reached, it would follow that the typhoid germ from the sewers of Chicago, by way of the drainage canal, do not reach as far as Peoria, and in further support of this view we have the direct evidence secured by the results of the experiment upon the duration of life of the typhoid fever germ showing that in the waters of the Illinois river it does not live for a period of more than three or four days. I am of the opinion, therefore, that the typhoid germ could not pass from the sewers of Chicago by way of the drainage canal to Lake Peoria and be deposited there for a period of a month. And further, experimental data alluded to above indicate that the conditions as

they exist today are hostile to the life of the typhoid germ and therefore they would be destroyed before reaching Lake Peoria.

6818 I am of the opinion that the typhoid bacillus would not reach as far as Lake Peoria and therefore water leaving Lake Peoria could not possibly contain more infectious and dangerous pollution than is at present in the diluted sewage entering the Bear Trap dam at the foot of the canal.

6819 From all data available concerning the character of the water of the Illinois river, the agencies at work in the river affecting chemical and bacterial changes, all evidence showing a bacterial purification of the river at Lake Peoria, and added to this the positive results from experiments instituted and carried out by Dr. Zeit, Dr. Jordan and Dr. Russell, I am very clearly of the opinion that typhoid fever germs coming from Chicago sewers do not reach the lakes and slack water portions of the Illinois river above Peoria. It is my opinion that by no possibility and under no conditions of the river can the number of typhoid fever germs at any point be as great as they are at the Bear Trap dam at the end of the drainage canal.

6821 In view of the extent, quality and kind of investigations bacteriologically, chemically and otherwise that have been made in this case being so extensive and exhaustive as they are, it is my opinion that there is no evidence which could establish the conclusion clearly and decidedly that the waters of the Illinois river at Grafton are infected with sewage from Chicago.

6822 I do not believe that typhoid fever from the sanitary district can find its way to the water supply of the city of St. Louis through the intake at the Chain of Rocks.

6824 For reasons which have been given repeatedly in this examination, conditions which obtain in the river from the self-purification of the same, all of which in my opinion contribute to the practical removal of all sewage as such from the river at Grafton, I should not attribute, beyond any reason-

able doubt the principal portion of the increase of typhoid fever in St. Louis to the infected sewage of the sanitary district of Chicago.

6825 From the evidence already given in this case and particularly the positive results of the experiment by Doctors Zeit, Jordan and Russell, in which they have demonstrated that the typhoid germs from the city of Chicago can live but a short period in this sewage laden water, such period covering, according to those observations perhaps three or four days, it is my opinion that the sewage of Chicago does not favor the longevity or growth of germs from Peoria or any other city also emptying its sewage into the river, but on the contrary the same agencies which have operated in this river, which have tended to diminish the viability of typhoid fever would still be operative upon typhoid fever germs coming from points below.

6826 Even though the population of Chicago should increase to 5,000,000 and with a typhoid fever epidemic, the sewage discharged from the sanitary district into the canal would not be an immediate and impending danger to the people of St. Louis and those living on the Missouri side of the Mississippi river, using the water of the Mississippi for drinking purposes.

6828 Assuming that there is an increase in typhoid conditions in St. Louis over normal conditions, since the opening of the canal, for reasons which have been repeatedly stated in this examination, it is my opinion that such increase could not be due to the opening of the canal and that the cause for such increase must be looked for at points nearer the intake, than from the sanitary district of Chicago.

CROSS-EXAMINATION, by Mr. Jeffries:

If the urine and excreta of a typhoid patient are discharged into 60 gallons of distilled water, the typhoid fever germs would

have a tendency to live longer in such condition than if discharged into 197 gallons of distilled water.

6830 The influence of dilution by the lake water, tends to dilute sewagic matters placed in the river, and in so far tends to prolongation of the life of the bacteria, yet the river today is decidedly of sewagic character so that in my opinion the longevity of the typhoid organism would not be very markedly different before the introduction of the quantities of lake water and conditions as we now find them; and in addition to that there is another factor, the river as I formerly knew it and had observed it was quiet, with very little current, and today there is a decided current tending to cause such organisms to pass out of the Chicago river in short periods. Assuming that pathogenic bacteria from Joliet passed down the Illinois river as it existed prior to the opening of the canal, the introduction of 250,000 cubic feet of water per minute into the Illinois river would tend to increase the speed of the current and therefore tend to push pathogenic bacteria farther down the river than they would prior to the opening of the canal.

It is clearly my opinion that the life of the pathogenic germs would not be materially increased by such dilution. If 500,000 cubic feet of water per minute were discharged into the canal, it might possibly prolong the life a little, but the pathogenic germs entering the river at Joliet would still be subject to the germicidal action of sewage waters.

6833 If 500,000 cubic feet of water per minute passed through the drainage canal the addition of this volume of water, as already a matter of evidence and opinion in this case, tending to increase the rate of flow of the stream, it would be self-evident that solid suspended particles or dissolved matters would be pushed farther down the stream, because of the inflow of such river, and further, the effect of dilution might possibly tend to increase the longevity of the pathogenic germs, but the exact degree of such prolongation could only be determined by a matter of experiments. While it is true that the increase of the flow of the river increased the speed of the current and

is probably true to some extent that a large number of these small cities are situated so that the sewage discharges, domestic and manufacturing wastes are discharged into swamps and pools and basins. What is true with reference to urban population, I should expect to be more particularly true of the rural population. The large part of the sewage is deposited in such a way that it never finds its way into the streams of the Mississippi watershed in an unpurified condition. Ultimately all drainage reaches the watercourse. As a general opinion, I would say that more than half the sewage from rural sources is purified before it reaches the stream.

6900 If I remember correctly the stream velocity of the lower Mississippi is less than the stream velocity of the upper Mississippi. The stream velocity of the Mississippi river below St. Louis, at a time reaches over five miles an hour. I do not know the average stream velocity of the upper and lower Mississippi rivers. (Tabulation offered in evidence showing the death report from typhoid fever in cities lying tributary to the Missouri river and also tributary to the Illinois river, exclusive of Chicago and also total number of deaths reported from typhoid fever in cities lying tributary to the Mississippi river, and deaths in Chicago and St. Louis respectively, as reported by the respective Boards of Health of said cities. These statistics being for the period beginning with the year 1890 to the year 1902 inclusive.)

6903 PROF. W. P. MASON, examined in chief by Mr. Todd:

Am professor of chemistry in the Rennselaer Polytechnic Institute of Troy, N. Y. I have been in that institute, in the chemical department, as professor of chemistry, and previous to that, as assistant professor in chemistry, for over 20 years. I have made a special study of water analysis, especially the examination of potable water for city supply. I have had much experience in the interpretation of chemical analysis of waters. I have made a special study of sanitary problems as related to water supply. I am the author of "Water Supply," published

by John Wiley & Son, and "Examination of Water," published by the same firm. As an expert, I have reported upon and testified in legal cases regarding the water supply of the following cities and towns of the United States:

6905 New York; Brooklyn; Philadelphia; Washington; Columbia, S. C.; Greenville, S. C.; Danville, Virginia; Birmingham, Alabama; Meridian, Mississippi; Denver, Colorado; Indianapolis, Indiana; Duluth, Minnesota; West Superior, Wisconsin; Buffalo, New York; Elmira, New York; Albany, New York; Troy, New York; Cohoes, New York; Newark, New Jersey; Newburg, New York; Waterville, Maine; Waterford, New York; Providence, Rhode Island; Bath, Maine; Rennsslaer, New York; Erie, Pennsylvania; Hot Springs, Arkansas; Atlantic City, New Jersey; South Hampton, New York; Burlington, Kansas, and sundry others that I can not remember.

Q. Who were the parties in the suits to which you refer?

A. Sometimes these suits were pending between the city and the water company. Sometimes they were between rival filter companies. Sometimes they were investigations in which there were no suits, the city merely wishing to secure the best possible supply and asking advice thereupon.

Sometimes I was employed by the city as against the water company; sometimes by the water company as against the city.

I have examined the water supplies of Paris, Hamburg, Copenhagen, London, Liverpool, Hague, Stuttgart, Lubeck, Amsterdam and sundry others.

6906 I am familiar with the literature with reference to all the foreign and American typhoid fever epidemics. In the instances of water examinations to which I have already testified, some questions involving typhoid fever arose therein, as for instance, Bath, Maine; Cohoes, New York; Albany, New York; Buffalo, New York; Waterville, Maine and possibly one or two others. I do not remember which ones now. I made

more or less of a study of Asiatic cholera in Sicily and Italy, more particularly at Messina.

6907 I have examined and studied the bacterial and chemical analyses of the waters of Lake Michigan, the drainage canal, the Des Plaines river, the Illinois river, the Mississippi river, and the Missouri river as made by Professors Jordan, Palmer, Gehrmann and Burrill, the same being published in what is known as reports of Streams Examinations, published by the Sanitary District of Chicago. I am acquainted with the Chicago river, the drainage canal, the Des Plaines river, the Illinois river, and the Mississippi river from Grafton to St. Louis. I went on a boat from the water front to Lockport, down the drainage canal, by daylight. I afterwards followed the course of the river in trolley and on train as far as La Salle and then took a steamer and went from La Salle in daylight to St. Louis, tying up at night so that no places were passed in the dark. On arrival at St. Louis, I visited the settling basins and saw them being cleaned. I have made a special study of bacteriology as applied to water investigations.

6908 I have read of the experiments made with the bacillus prodigiosus by Dr. Ravold. (Question asked assuming all the conditions as testified to by Dr. Ravold in relation to said experiment.) Assuming all of the facts stated to be

6909 true, my opinion is that in view of the large number of the bacillus prodigiosus introduced and the small number found the results of that experiment show a very considerable death rate of the bacillus prodigiosus and by inference at least as large a death rate of the bacillus of typhoid fever under the same circumstances. In my opinion, it seems that the importance attached to this experiment is to show that to the extent that a bacillus prodigiosus represents a bacillus of typhoid fever, a very large death rate has been proven as occurring

among the bacilli of typhoid fever under those circumstances.

6910 The bacillus of typhoid fever may remain alive in soil for a period of at least weeks and possibly months.

The question of the longevity of typhoid fever in water may be best stated by saying that it dies out in water more or less quickly en masse, although some individual cells, being more resistant may remain alive for a longer period. I should say that it would be right to limit it to a very much shorter period of time, that is it should be measured by days in water.

In the case of a relatively pure water the longevity of typhoid bacillus is greater than in one where it has to fight for existence with saprophytic bacteria.

It does not increase in nature outside of the human body although it may live saprophytically for a greater or longer period of time according to its surroundings. It will multiply rapidly in milk, most milk epidemics having been caused by such multiplication.

6911 Stamford, Connecticut, had a milk epidemic. There are a good many milk epidemics from British sources that have been reported by Harte. The laboratory conditions are more favorable for the longevity of the typhoid bacillus. In experiments made by the Massachusetts Board of Health in a large tank, 12 feet deep, suspended in Merrimac river water, the longevity of the colon bacillus was limited to 11 days. The germ of typhoid fever will not live as long in polluted water as in pure, sterilized water.

6912 I believe that the typhoid bacillus would live in the water of the drainage canal, Des Plaines river and Illinois river for a less period of time than in sterilized water, or water of greater purity, from a bacteriological standpoint and that it would be limited in length of life to a question of days. I base my opinion upon the fact that where the experiment has been upon a large scale, as in the instance in the Massachusetts report, quoted, we get a shorter period of time during which the

bacillus will remain alive. In other words as we approach the conditions of nature the opportunities for its destruction seem to be greater than in the conditions obtaining in the laboratory experiment.

6913 The dams in the Illinois river increase the opportunity for sedimentation, although I do not believe they will increase it to an extent that amounts to very much, acting more as riffle boards than dams, they being submerged. I do not think the influence of those dams by sedimentation is very great, although I think it to be something.

The Illinois river when the water is high overflows its banks and the water settles back to the right and left to a very considerable extent. I noticed that as I went down the river, on a boat, that the trees were standing out in the water, trees apparently growing in one or two feet of water, and such overflow represented a considerable acreage.

The effect of such overflow upon sedimentation will be to spread out the water over a large area thereby giving that particular part of silt the opportunity of reaching the ground after falling a comparatively short distance. Sedimentation is very marked where the water holding the material to be sedimented is spread out in narrow sheets.

6914 In a clear stream gravity alone would operate upon the bacteria and they would settle therefore slowly. In a turbid stream bacteria will settle more quickly. Sufficient water from Lake Michigan, assuming the maximum amount is 800,000 cubic feet per minute, could not be carried through the drainage canal into the Des Plaines and Illinois river so as to create a condition of purity and clearness that would preclude the operation of sedimentation. There is enough turbidity present in the system of the Illinois river to prevent any such condition obtaining.

6915 Assuming that the entire sewage of Chicago should be diverted into the drainage canal and that 800,000 cubic feet of water per minute from Lake Michigan should pass over

the Bear Trap dam, the turbidity yet remaining in the Illinois river would be sufficient to permit of sedimentation of bacteria. Dilution diminishes the chances of a person drinking the water of contracting disease from pathogenic germs. The greater the dilution of sewage the less the danger from infection.

6916 The addition of Lake Michigan water to the sewage of Chicago is a benefit to the sanitary condition of the Illinois river considered from the standpoint of dilution alone.

The addition of Lake Michigan water to the sewage of Chicago is a benefit to the sanitary condition of the Illinois river considered from the standpoint of chemical and bacterial changes taking place therein.

If a sufficient volume of Lake Michigan water should be added so as to cause the Illinois river to overflow its banks in the manner I saw it, under those circumstances there would be a greater opportunity for sedimentation because of such overflow, as per the illustration that I have already given.

The physical condition of the Illinois river, inasmuch as the river is one which readily overflows its banks, permit of a better opportunity for sedimentation than would obtain in a river like the Hudson where no such overflow of the banks is possible, the banks being very much higher.

My opinion is that the waters of the Illinois do not have any appreciable effect, good or bad, upon the waters of the Mississippi river into which it flows.

6917 The Illinois river has no appreciable sanitary effect on the Mississippi although it is possible it may slightly improve the mixture, inasmuch as if there is any difference between the Illinois at Grafton, and the Mississippi river at Grafton and the Missouri river above the junction, that difference is in favor of the Illinois river at Grafton. At the same time I do not think there is very much choice. The colon bacillus is of longer life in soil than it is in water. I believe a typhoid bacillus passing from the sewers of Chicago would die before Grafton was reached. It is possible that some resistant

analyses were made, as a rule, daily at one point, located at the upper confines of the city of New Orleans and where the experiment station took its water for experimental purposes. The results of the chemical and bacterial analyses for the entire period were published in the report on Water Purification, published in New Orleans in 1903, by the Sewerage and Water Board of New Orleans. I have prepared a table showing the composition of the Mississippi river water at New Orleans, based upon the chemical and bacteriological data for the months between December, 1900 and August, 1901.

Table is reproduced on page 6876.

6878 The analyses show that apart from the nitrogen as nitrates and nitrites, that the water is characteristic of the non-polluted water of this region. An abundance of oxygen is always present in the water, showing that the organic matter has been decomposed to about the limits, the number of bacteria are very low and are chiefly associated with the suspended matter. When the suspended matter is removed the water is of excellent quality.

Colon determinations were made during the flood seasons, that is from December, 1900 to April, 1901.

Bacillus coli was only found on three occasions during the five months of the tests. It was found during the first week of December, 1900. It was not found subsequent to that date. When the bacilli were found in 1900 they were found in a small volume of water, namely 1 cc. They were not found subsequent to the first week in December. The presence of these organisms in the water at this time and not at any other times is explained by the fact that on the bank of the river immediately above the intake of the water purification station a number of house boat men and squatters were quartered. During the low water season these people had thrown their feces on the bank of the river, and during the rise it is easy to account for the presence of bacillus coli in the intake of the water purification station at that time, especially so because the intake was located near the

bank of the stream and was suspended from a house boat, but in comparatively shallow water.

6879 100 coli determinations were made during this investigation and the coli was found present only three times. I arrived at the conclusion from the results of these coli determinations that no unpurified sewage was present in the Mississippi river at New Orleans. Assuming the velocity of the stream at four miles an hour, which is neither the maximum nor the minimum, the sewage from Baton Rouge would reach New Orleans in 33 hours after it was discharged into the Mississippi river. The velocity of the Mississippi at New Orleans may be taken at four miles per hour. A fair average of velocity for that river from Cairo to New Orleans is about four miles per hour, certainly no more. I never figured out the discharge of the Mississippi at New Orleans but I have it from the report of the Mississippi River Commission for 1900 on page 18, which is as follows:

Maximum, 1,353,000 cubic feet per second.

Minimum, 191,000 cubic feet per second.

Average, about 685,000 cubic feet per second.

6880 The methods as pursued in my chemical analyses of the waters at New Orleans, and the technique employed in the bacteriological determinations and coli determinations are substantially what are known as the standard methods used by the Massachusetts Board of Health and employed by the different chemists and bacteriologists that have testified in this case. I have prepared a chart based upon the monthly averages of the chemical and bacteriological analyses of the Mississippi river at New Orleans, which chart is reproduced on page 6880.

6881 Mr. Jeffries: Let the record appear that complainant objects to any and all charts, maps, tables or plats being introduced which are based upon the chemical analysis and determinations by this witness in the waters of the Mississippi river at New Orleans, for the reason that they are incompetent

and immaterial and have no bearing upon the issues involved in this case.

This chart is made for a clearer demonstration of the main results expressed in the table previously presented in evidence. It gives the numbers of bacteria, the nitrogen as albuminoid ammonia, the nitrogen as nitrites and the amount of suspended matter averaged by months for the same period of time as was covered by the data presented previously in evidence. I also prepared a chart based upon the computations which I have already introduced in evidence, of the relative pollution of the Mississippi river water at various points. This chart is entitled "Relative Pollution of the Mississippi River Water," and is reproduced on page 6882. I also made a graphical presentation of the same which appears on page 6884.

6883 This shows the relative pollution of the Mississippi river water, no allowance being made for self-purification of streams at different points along the course of the stream as follows:

At New Orleans; at the mouth of the Red river; at the mouth of the Yazoo river; at the mouth of the Arkansas river, and at the mouth of the Ohio river.

This chart shows the estimated mean flow in cubic feet per second, the total population of the water shed above the various points and the dilution of the present amount of sewage with water in cubic feet per second per 1,000 persons.

6885 This table shows that the Mississippi river as it flows to the Gulf dilutes the sewage more and more as it proceeds on its way to the Gulf. I also prepared a chart showing the accessions of sewage to the Mississippi river from Cairo, Illinois, to New Orleans, which is reproduced on page 6886.

6887 It shows that the fresh accessions of sewage poured into the stream below the mouth of the Ohio are very small in amount, namely that from the district immediately below the Ohio and above the Arkansas river the dilution is 2,710 cubic feet per second per 1,000 population, below the Arkansas river

4,610 per 1,000 urban population; below the Yazoo, 11,700 per 1,000 population and below the Red river, 59,900 per 1,000 population.

In this table as in the ones that preceded it no allowance has been made for the self-purification of streams.

Also made a chart showing relative dilutions of sewage in cubic feet per second of the Mississippi river at points of pollution as compared with the Connecticut and Merrimac rivers, which chart is reproduced on page 6889.

6889 This diagram was made primarily to contrast the two Massachusetts streams with the Mississippi river. The Massachusetts streams receive so much sewage in the form of fresh accessions below the points of observation that the amount of sewage in the river water as it proceeds down the river within the limits named are always in greater proportion as shown by the observations. While on the other hand as sewage is carried down the Mississippi river below Cairo it is always in increasing dilution, the fresh accessions of sewage never being of sufficient amount to maintain the concentration of sewage which existed at Cairo. The reasons for this status of affairs are that the Mississippi river below Cairo is levied and that the population is relatively small. The banks slopes back from the river for a greater part of the distance, while in the case of the Connecticut and the Merrimac rivers the streams flow through a country which is higher than the level of the water in the stream and constant fresh accessions of sewage are received. The literal population is relatively larger.

From my knowledge of the amount of pollution entering the Mississippi river through its tributaries and the population living upon the watershed, and from the chemical and bacterial and coli determinations, the results of which I have offered in evidence in my testimony.

6890 In my opinion there is not the slightest evidence that any unpurified sewage exists in the water at New Orleans apart from that small amount which may occasionally have been washed from the banks of the stream outside of the levies

and in the immediate vicinity of the water purification station intake during the time when the tests mentioned in the question asked me, were made.

CROSS-EXAMINATION, by Mr. Jeffries:

By unpurified sewage, I mean sewage which has not undergone the cycle of changes which would obtain when sewage is mixed with an adequate quantity of water in a running stream, and I mean sewage which has not lost its previous bacteriological character. The main effect of dilution is to furnish an adequate quantity of oxygen for the oxidation of the organic matter contained in the sewage. This can also be obtained by aerating sewage by passing it over dams, but of course not to the same degree. Even though the city of Baton Rouge is situated 132 miles from, and within a 33-hour flow of, the city of New Orleans, any sewage discharged into the river from Baton Rouge has evidently become purified within the time it reaches New Orleans within 33 hours.

6891 The facts are as I have stated them, that there are no bacterial evidences of sewage at New Orleans, in spite of the fact that sewage reaches the river.

6892 I do not think that it is a fact that the element of dilution has more to do with the small quantities of bacteria contained in the waters of the Mississippi at New Orleans than other bacterial and chemical elements known in sanitary science. Because in any other river with which I am acquainted, rivers in which the dilution of sewage in some instances have approximated the dilutions of the sewage at New Orleans by increasing the volume of the samples taken, I have been able in all of these other cases to demonstrate the presence of the bacillus coli communis. At New Orleans I was usually unable to do so. Neither was I able to demonstrate

the presence of the bacillus coli communis nor, generally speaking, of any of that gas producing type of bacteria.

6894 To a degree, it is a fact that this table of analyses bears the evidence of a prior sewage pollution of that water.

Q. Is it not a fact that if the chemical and bacterial contents of a volume of water at the point in the Mississippi river where it was examined at New Orleans was concentrated to the same volume of water as existed in the river at Cairo that the chemical constituents which you found in the water at New Orleans would have been greater and larger and more numerous?

A. If the dilution were less the chemical content would be relatively greater to the same degree.

6896 There are slight changes in the bacterial and chemical conditions of the water, on account of flood conditions and water conditions, but not such marked changes as on the tributaries of the stream, and the smaller the volume of water the greater would those changes manifest themselves.

6897 The climatic conditions of the territory traversed by the lower Mississippi is higher in temperature on an average, from one end of the year to the other, than the upper Mississippi and its tributaries. This table shows large quantities of free ammonia and larger quantities of nitrates and nitrites during low temperature than they do during high temperature.

The temperature of the water in the Mississippi river at New Orleans for the month of February, 1901, averaged 46 degrees Fahrenheit and during the month of August, 1901, about 86 degrees Fahrenheit.

6898 A large part of this urban population is contained in small cities of 4,000 and upwards, that are far removed from the main bed of the various tributaries of the Mississippi although situated upon the water shed of those tributaries. It

processes in use for the clarifying of river waters used for the supply of cities.)

6867 CROSS-EXAMINATION, by Mr. Jeffries:

With reference to the depth of a stream, at which the current of the river, with reference to its surface and its bed, is most rapid, it is about from .1 to .2 below the surface, so that if a stream is 10 feet deep, the most rapid place would be from one to two feet below the surface and in the center of the stream.

6869 ROBERT SPURR WESTON, examined in chief by Mr. Todd:

Gradua[illegible]d at Amherst college in 1891, with degree of Bachelor of Science.

6870 I was then employed as a chemist for about three years. With the American Sugar Refining Company, and also on a plantation in Louisiana. After that I was a student in the Institute of Technology and in the University of Berlin, and besides that I have been a volunteer worker in the laboratories of the Massachusetts and the German Imperial Boards of Health. Since then I have been engaged in sanitary work. In 1895 I was connected with the Louisville water purification experiments and subsequently have been connected with water purification experiments at West Superior, Wisconsin, at Washington, D. C., and other places.

In 1900 I was in direct charge of the water purification station at New Orleans and conducted an investigation lasting eight months as to the feasibility of purifying the Mississippi water. I have been in private practice, exclusive of this last period, for six years.

(Witness reads list of the principal cities and their distances from New Orelans lying upon the Mississippi river or its tributaries).

6871 The United States Census for 1900 showed the population in cities of 4,000 or more in the Mississippi valley to be about 9,000,000, including Chicago. I have prepared an

estimate of the amount of sewage sewering into the different rivers, which make up the watershed of the Mississippi river.

I have assumed that cities which have a population of 25,000 and over will discharge 175 gallons per capita of sewage per diem. I have assumed that the remainder of the urban population would produce 100 gallons per day per capita of sewage.

6872 I estimated the amount of sewage from large cities, that is, cities above 25,000 population, to be 1,174,250,000 gallons per day. I estimated the amount of sewage from the remainder of the urban population, that is, the remainder of the population of cities from 4,000 to 25,000 to be 342,000,000 gallons per day, making a total of 1,516,250,000 gallons a day. This is equivalent to a flow of 2,310 cubic feet a second at New Orleans.

6873 These dilutions may be expressed in three different ways:

A. Maximum dilution 1 of sewage to 586 of water.
Minimum, 1 of sewage to 83 of water.
Average, 1 of sewage to 296 of water.

B. Expressed as cubic feet per second of sewage per 1,000 urban population:

Maximum, 150. Minimum, 21. Average, 75 cubic feet per second per thousand urban population for the year 1900.

C. As gallons of water per diem per capita of the urban population:

Maximum, 16,160. Minimum, 2,262. Average, 8,190.

In 1900 and 1901 an experiment was conducted for eight months and data was collected for somewhat longer time to determine the best method of purifying the Mississippi river water at New Orleans. The data consisted of analyses, engineering data and reports.

6874 I had charge of the chemical and bacteriological analyses conducted at New Orleans at this time.

These surveys of the waters of the Mississippi took place from the last of November until the following September and

upon the amount of water which went over the sides of the river. If the banks were very low as they are in many places, and consequently the river section greatly widened, there would be no material increase in velocity. There might be a decrease. That would have no material influence whatever on the people of the State of Missouri.

6947 I do not believe that there could be any accumulation of germs taking place in the Illinois river gradually said accumulations afterwards being washed out by floods and causing widespread disease in the sections below and I do not so believe because I observe that we do not have epidemics following floods of that kind.

6948 I do not believe that the number of typhoid bacilli at Lake Peoria is ever as great as they are at the Bear Trap dam. As to the Detroit epidemic, I talked the matter over with Prof. Williams, and it seemed to me that there might be some doubt with reference to the connection between typhoid fever in Detroit and the dredging of the Black river.

6949 I have no knowledge of the presence of infected Chicago sewage in the Illinois river at Grafton, and I believe that the use of the water of the Mississippi at the Chain of Rocks, because of the admixture of water from the Illinois river, would not be a menace to the health of the inhabitants of St. Louis. I do not consider that the waters of the Illinois river under the conditions obtaining, commingled with the waters of the Mississippi river, are a menace to the inhabitants of the State of Missouri living upon the Mississippi river and using the Mississippi river water for drinking purposes at points on the Missouri shore. Assuming that the only pollution upon the watershed of the Mississippi and its tributaries above the intake of St. Louis was that derived from the sanitary district of Chicago, and having in mind the large amount of typhoid fever in Chicago, I do not believe that dangerous infection and dangerous pollution might, under existing conditions, find their way into the water supply of St. Louis. Assuming the same conditions,

I do not believe that typhoid germs would be able to find their way into the water through the intake tower at the Chain of Rocks, and become a menace to the inhabitants of the city of St. Louis. I do not know of any analyses or experiments that justify the assumption of Prof. Sedgwick that typhoid germs may find their way into the sewage of Chicago and pass on to the Mississippi river and find their way into the intake at the Chain of Rocks, but on the contrary, I am of the opinion
6951 that the charts which I have offered in evidence show that there is no connection between typhoid fever in the city of St. Louis and the city of Chicago, and were it liable that typhoid germs should pass into the water at the intake I should expect that the curves of typhoid fever in St. Louis and in Chicago would show parallelism whereas they show quite the reverse.

Assuming that there has been an increase in typhoid since the opening of the canal, I would not, beyond reasonable doubt, attribute the principal portion of the increase to the infected sewage of the sanitary district of Chicago. On the contrary, I would attribute any increase in typhoid fever which might have taken place in St. Louis to infection from nearer points, because of what I have already testified to, as my belief that the nearer the point of infection the greater the danger, and because further, that the charts which I have offered in evidence show that there is no relation between the typhoid fever in Chicago and typhoid fever in St. Louis.

6953 In my opinion the addition of the Chicago sewage does not favor the growth of the typhoid bacilli introduced at Peoria. I do not consider that the Illinois river water polluted and infected by the sewage from Chicago, has rendered less safe the water supply of St. Louis. I base my opinion upon the fact that the Illinois river at Grafton furnishes water which is in quality better than it was before the opening of the canal, and better or at least as good as the water of the Mississippi

into which it flows. Assuming that the Chicago sewage from 1,500,000 people should be discharged into the drainage canal and assuming that a typhoid epidemic of extraordinary proportions should become prevalent among the residents of the sanitary district, it would have no appreciable effect on the people of St. Louis and those people living on the Missouri side of the Mississippi river below Grafton, who use the water of the Mississippi river for drinking purposes. I do not regard the water of St. Louis as a safe drinking water as it is at present treated with settling basins.

6956 Sedimentation should be supplemented by filtration. In this opinion of mine I entirely concur with what has been stated by Messrs. Hazen and Fuller in a report on the water supply for the city of St. Louis, dated 1902, in which Mr. Hazen says, after describing the method of filtration which he proposes, on page 77, "I believe that the hygienic character of the purified water will be entirely satisfactory."

And on the same page: "I believe that the raw water, although polluted far beyond the point where it should be used in its raw state is very much less polluted than many or most of the river waters used by American cities. Purification will remove a very large percentage of the bacteria and the elements of danger in the raw water. So far as there is danger to health in the present water it will be reduced by filtration to an almost inappreciable amount."

Mr. George W. Fuller, in commenting upon Mr. Hazen's statements in this report says, on page 81 of the same report: "With regard to this method of purification for the St. Louis water supply, it is my judgment that it will yield a water of satisfactory appearance and hygienic quality with proper construction and operation of the works and that it is the best and most applicable method for the conditions existing at and near the Chain of Rocks."

My opinion is that the addition of Chicago sewage via the drainage canal to the system of the Illinois river would not

add any additional expenses to the purification of the Mississippi water by filtration at the Chain of Rocks. The installation and operation of the plant would not be greater in point of expenses by the addition of the Chicago sewage as it now is added to the system of the Illinois river.

6957 CROSS-EXAMINATION, by Mr. Jeffries:

6958 (Regarding the bacillus prodigiosus experiment made by Dr. Ravold and comparing the finding of that bacillus to the finding of typhoid bacillus the same number of times, witness states). My opinion would be that a water sampled at the Chain of Rocks 720 times and the typhoid bacillus being found twice, that it would be a water certainly containing typhoid fever, as the facts show, but not to such an extent as to be prejudicial to a city supply, provided the supply were used after filtration.

6959 Assuming that the average longevity of a typhoid germ is somewhere between one and thirty days, there is no question but that there would be a variation in the longevity although a small one, if such germs be deposited in running streams, as the conditions under which it finds itself might vary.

6960 My opinion is that in consideration of the facts regarding the Chicago sewage being dumped into the Illinois river, as at present, and the facts concerning the conditions of the Illinois river, that the germs of typhoid fever coming from Chicago sewers would be destroyed en masse by the time the mouth of the Illinois was reached, although some resistant organisms might go beyond that point, such organisms, however, representing a small number and in my opinion low vitality.

6963 If a gallon of infected typhoid dejecta be deposited in the waters of Lake Michigan at a point free from sewage contamination, the typhoid bacilli would disappear first. The typhoid bacillus would disappear before the lake bacteria would

disappear and before the ordinary sewage saprophytes would disappear.

6964 If you have a certain number of bacteria present, in water and then should dilute the same you would diminish the number of bacteria there because they would be further separated. I mean, when I say "diminish the number," that you would diminish the number per gallon.

6965 The conditions as stated in the question, of practically no current and a green scum before the opening of the canal and a decided current and no scum after the opening of the canal, those conditions being as stated, the two waters before and after the opening of the canal being equally infected, by supposition, the conditions obtaining before the opening of the canal would be more favorable to the destruction of typhoid bacilli than those obtaining after.

My opinion is that those conditions would, from a practical standpoint, increase the longevity of the typhoid germ, but I do not believe, and it is my opinion in fact, that such increase would be not material from a practical standpoint.

6966 The removal of the dams and the leveeing of the Illinois river from one end to the other would interfere with sedimentation and its resulting purification by sedimenting bacteria of the pathogenic type, and would increase the velocity of the stream.

6967 Q. Professor, in the tables introduced in evidence by Professor Jordan covering the bacterial count examination of the waters in the Illinois river at Grafton, from October 1, 1901, to December 24, 1901, and on the Mississippi at Grafton from October 21, to December 24, 1901, the maximum bacterial count in the Illinois river at Grafton was 123,000, the minimum 210, the average bacterial count for the period in the Illinois river at Grafton 6,900; in the Mississippi river during the same period the maximum bacterial count was 3,700; the minimum 360, the average 1,300. Taking into consideration your knowledge of the population upon the watersheds of the respective

rivers, which would you consider from this bacterial exhibit the better for sanitary purposes?

A. So far as the total count is concerned it shows the Illinois at Grafton to be inferior to the Mississippi at Grafton. Where those bacteria came from is of course important. Is it true that they represent ordinary soil bacteria washed into the Illinois river because of special conditions in the way of local rainfall, or don't they? I don't know. Right on the fact of it, judging merely from the count as it stands, the Illinois is inferior to the Mississippi at those points.

6968 It is a fact that chlorine has been reduced all along the line by the opening of the canal, but it is also a fact that albuminoid and free ammonia have been reduced as well. Nitrates towards the end of the canal have been increased. I have made no estimate which would enable me to say whether or not the chlorine has been reduced in the same proportion that the other items have been reduced, such as ammonia, free and albuminoid. All that I can tell you is that they have been reduced but their relative rates of reduction I can not tell you. I do not think the results of examinations made from May to December should be compared with the results of examinations made from May to June.

6969 I do not feel that it is wise to compare waters of the same stream at such widely different periods of the year because in one instance you get the benefit of the spring changes, and in the other case you get whatever influences may come from the changes of the summer and autumn.

6970 In the charts on typhoid deaths in St. Louis and Chicago I placed St. Louis one month in advance of Chicago because the deaths of Chicago, due to typhoid fever in one month, if they be related to deaths from typhoid fever in St. Louis, such relation will show in the death rate of St. Louis for the following month. Therefore, I moved the death rate of St. Louis one point to the left merely for the sake of easy comparison. I might have left them where they naturally would fall. Under those

It sems to me that a nearer approach to the truth is obtainable by stating the typhoid rate as so much per one hundred thousand inhabitants.

6925 The percentage method is not the commoner one in use, although it is used, the more common method of stating it, being the determination of number of deaths from typhoid per 100,000 people. The reporting of non-fatal typhoid cases is more general now than it was formerly.

6926 Chart entitled, "Deaths from Typhoid fever in 1900, 1901, 1902 and 1903, as reported in Chicago and St. Louis official Health Reports."

6928 The deaths in St. Louis are stated one month in advance of those for Chicago, because of the length of time it would take a typhoid fever germ—should it go so far as St. Louis—to get there, because of the length of time that it would take to produce typhoid fever of fatal character after an invasion of the victim had taken place. In examining this chart and observing the fluctuations of the solid line representing deaths in Chicago and of the dotted line representing deaths in St. Louis, I observe that the two lines are by no means parallel.

6931 From an examination of the charts just presented I am of the opinion that no relation whatever exists between the typhoid fever as represented in Chicago and as represented in the city of St. Louis. In other words, I am strongly

6932 convinced that typhoid in St. Louis is not produced by typhoid fever in Chicago.

It will be seen from an examination of those charts that the curves of typhoid fever are far from being parallel for the two cities. In many instances the rise of the curve from Chicago is coincident with the falling of the curve for St. Louis, particularly so for the month of August, 1902, when the typhoid in Chicago grows from 44 to 193 and the typhoid in St. Louis drops from 26 to 21.

Have prepared a chart of coli determinations based upon Prof. Jordan's tables of coli determinations made for the year 1901. Chart is reproduced on page 6933.

6934 Inasmuch as bacillus coli communis is a constant inhabitant of the human intestine it is a valuable indication of the presence in the water of discharges although it bears no evidence as to whether those discharges came from a healthy or diseased person.

6935 From an examination of this chart I observe that the bacillus coli communis is more frequently found in the waters of the Mississippi river at Grafton, the Illinois at Averyville, the Missouri at Bellefontaine and the Mississippi at the St. Louis intake and the Illinois at Pekin than it is in the Illinois at Grafton, operating upon 1 c.c. of water. Operating upon the same quantity of water I observe that the Mississippi river at the Chain of Rocks contains the bacillus coli communis most frequently upon the Missouri shore, next in frequency at the intake tower, next in frequency in mid-stream and least in frequency on the Illinois shore.

Judging from the bacillus coli communis contents of the several waters, operating upon 1 c.c. as stated, the relative purity of the waters in question would stand, first in purity, Illinois river at Grafton; (2) Mississippi river at Grafton; (3) Illinois river at Averyville; (4) Missouri river at Bellefontaine; (5) Mississippi river water at the St. Louis intake and (6) the Illinois river at Pekin.

Basing upon the same data from the several waters taken at the Chain of Rocks, the relative degrees of purity would stand most pure water from the Illinois shore, next in purity from the mid-stream, next in purity from the intake tower and least in purity from the Missouri shore.

Basing my reply on the bacilli coli communis contents, the Illinois river at Grafton is the most pure. The Mississippi river at Grafton is next and the Missouri river at Bellefontaine is the least pure. The source of pollution from a rural popula-

tion would come from such sewers as it possessed, together with what surface washing might result from its barn yards and from any other source of pollution which there was a surface origin. (Witness states towns in which typhoid fever epidemics occurred, in which infection came from rural population.) I have made an analysis of 205 British epidemics reported by Harte in a report entitled, "Water Born Typhoid made to the Parliamentary Committee of the British Medical Association." In 33 epidemics due to stream and reservoir water I found that the death rate was 9.85 per cent of the cases. In 75 epidemics due to well water I found that the death rate was 11.83 per cent of the cases and I found that in twenty epidemics due to milk the death rate was 12.79 of the cases, showing that a well water epidemic was distinctly more serious in character than an epidemic caused by water which had carried the typhoid germ some distance from the point of infection to the point where the water was used for purposes of drinking.

6937

I made an examination of 357 cases of typhoid fever in a typhoid fever epidemic which I examined in Waterville and I was able there to follow the course more clearly of each case and to get the physician's statement whether the case was a severe one or a mild one. Some of these cases used the city water supply, which was from a contaminated stream. Some of the cases used well water supply and those wells were contaminated. Some of those cases used both sources of water. I found that among the cases that used city water only 41.41 per cent were severe, it not being stated whether they were fatal or not, I rated a fatal case as a severe one naturally.

Among those cases not using city water I found that 61.29 per cent were severe, thus showing that the typhoid fever produced by city water was a milder type, and my explanation of that is that the typhoid germ having to struggle for existence in a river under adverse circumstances, when it arrives at the point where the water is drunk it is not capable of producing so

much poisonous material, or in other words not capable of producing so severe a case of fever if it produced one at all.

Mr. Whipple in his testimony in this case, stated that immediate pollution is very much more dangerous than remote pollution, a view which is entirely in accord with my views. Assuming that on April 1, 1895, the total number of wells in St. Louis was 4,846 and that the city chemist after an examination of 59 of those wells, condemned them as being unsanitary and assuming, further, that in August, 1895, upon the report of the city chemist condemning seven more of these wells, the Board of Health of St. Louis passed a resolution to the effect that the city chemist should make no further examination of the wells in question and since 1895 none of these wells has been condemned, I believe that the water of those wells was responsible for a portion of the typhoid fever in St. Louis, because I am a believer in greater danger coming from a polluted well water than from the water of a polluted stream.

6938 My reasons are based upon data such as that which I gave in answer to a previous question, showing that the death rate of well water epidemics was greater than that of stream epidemics, and showing that the intensity of fever from well water epidemics was greater than from stream epidemics. My opinion is that given points nearer and remote from the St. Louis intake, said points being located upon a water course flowing thereto, and said points all possessing typhoid in their sewer discharges, I would attribute the danger of typhoid fever in St. Louis greater from the nearer points than from those more remote. I do not think a typhoid bacillus lying in the sediment of a polluted stream for a period in excess of sixty days would be able to cause typhoid fever when taken into the human system after it had remained in such sediment for that length of time. I do not think that typhoid germs coming from Chicago through the drainage canal and deposited on the bottom of the Des Plaines and Illinois rivers, between Chicago and Peoria, would be able to retain their dangerous qualities

after such a discharge in the bottom of the river. I do not think the sewage from Chicago passing through the drainage canal into the Illinois river at different seasons of the year and at different stages of water in the Illinois river would be a danger and menace to the inhabitants of Missouri and the citizens of St. Louis using the water of the Mississippi. From the data introduced in evidence in this case, my opinion is that of the three rivers—the Illinois, Mississippi and Missouri, the Illinois represents the least impurity, although I do not consider that there is any considerable difference between the three, what little difference there is being in favor of the Illinois.

6940 The emptying of the Illinois river into the Mississippi river makes no material change in the character of the combined waters. What little change there is, is an improvement, but as I have already stated, the three waters are not widely apart. They are all about the same, any difference being in favor of the Illinois.

6941 I do not think the germs of typhoid fever could live in the sediment of the drainage canal or upon the bottom of the Illinois river for a period of from one to three years and retain their vitality. I do not know of any instance on record where a typhoid bacillus has lived for such a period. My opinion is that the water supply of St. Louis is not contaminated by the sewage of Chicago entering the drainage canal. An increase in the volume of water in the Illinois river floods the lowlands along the Illinois river. I saw it.

6942 It increases the opportunity for sedimentation by overflowing those lowlands, the principle being entirely similar to the one which I illustrated in my morning testimony. Sedimentation would certainly be greater if the volume of water was greater, for the more acreage that is overflowed by such water, the greater number of particles will have a short distance to drop before reaching their final resting place on the soil. All of the dams and lakes in the Illinois river would have an effect in increasing the opportunity for sedimentation

and such increased sedimentation would have a beneficial effect in the elimination and purification of polluted and infected waters coming into the Illinois river from Chicago.

6943 Assuming that the dams should be removed at a time when the maximum flow of water passing through the drainage canal was 800,000 cubic feet per minute, the sedimentation of objectionable material would be interfered with, but as I stated this morning, I do not think the beneficial effect of the dams amounts to very much and their removal, although it would diminish the purifying power of the stream through sedimentation, such diminution would not be great. The water of the Mississippi river at the Chain of Rocks prior to January 1, 1900, was not a safe and potable drinking water fit for domestic and drinking purposes after passing through the settling basins. (Same as to the Missouri and Illinois rivers.)

6944 The sanitary condition of the Illinois river at Grafton has been improved by the opening of the canal. The sewage discharged from the drainage canal has no appreciable effect upon the waters of the Mississippi and Missouri rivers at the Chain of Rocks.

6945 If an increased volume of water was discharged in the Illinois river, so far as particles which were in the main channel were concerned, they would doubtless be carried down stream more rapidly; so far as particles which might be contained in the waters which overflowed the lowlands were concerned, they would not go down so rapidly, and there would be a depreciation in the velocity of the current, and there would be an opportunity for sedimentation. An increase in volume of the Illinois river would cause an overflow of the banks and consequently there would be a depreciation in the velocity of the current because of that overflow and that portion of the water which was in the overflow would have low velocity and be given a better opportunity for sedimentation. Some portions of the main channel of the river might or might not have an increased flow in the unit of time, depending very largely

germs might make the journey, but the great mass of bacilli of typhoid fever would perish before the Mississippi was reached. There is such a thing as purification of soil, although it is a slow process. (Witness refers to an article by Savage, in the Journal of the Sanitary Institute, as an illustration.) I attribute the death of the typhoid bacilli in polluted water to the adverse conditions set up by the saprophytic bacilli which are present there in large numbers. My opinion is that there would be no material difference between the length of time in which a typhoid bacillus would live in a polluted stream as compared with the sediment of that stream.

6919 The difference between moist soil and the sediment of a running stream is that in one case you have only moisture present and in the other you have water present in quantity. I do not think that the time a typhoid bacillus will live in moist soil furnishes any criterion for its longevity in a running stream. (Witness again refers to the Massachusetts Board of Health tank experiments.) I know of no demonstration that shows that typhoid fever germs can and do

6920 and have continued to live in the sediment of running streams for a period upwards of two years as testified to by Mr. Fuller.

6921 My opinion is that typhoid fever bacilli coming from the sewers of Chicago would not be a danger and a menace to the inhabitants of St. Louis using the water of the Mississippi for drinking and domestic purposes.

It is my opinion that merely because the capacity of a reservoir is a thirty-day supply, it is not therefore to be assumed that water remains in that reservoir for thirty days. Much depends upon the construction of the reservoir. Many reservoirs are of stand pipe type, receiving their water and discharging it through the same orifice. Under such circumstances the pumps deliver to the mains and the reservoir merely takes the surplus of the pumpage. During periods of low pumpage the reservoir receives less, hence in reservoirs of that

character it is impossible to say how long any particular volume of water may remain therein.

6922 I have examined the typhoid statistics of the Illinois, Missouri and Mississippi watersheds above St. Louis, the same being the table of typhoid statistics which was introduced in evidence in this case just ahead of my testimony. I notice in the tabulated form of tables reported that for the years 1899, 1900, 1901, 1902 and 1903, the St. Louis deaths are reported as uniformly increasing, being 130, 168, 198, 222 and 288. I notice that Chicago is quite variable.

6923 I notice that the reported typhoid for 1900 upon the three watersheds, exclusive of Chicago, is 503, which is larger than the preceding year. This is in accord with the reported deaths in St. Louis for that year, the same being larger than the preceding year. It is not in accord with the deaths reported in Chicago, the same being smaller than the preceding year, so that for that one year it would seem that the deaths in St. Louis were not in accord with the watersheds of the three rivers, exclusive of Chicago, that they were with the death rate in Chicago itself, although for the next two years I do not notice that there is the same array of facts, my remarks applying only to 1900.

In the matter of the interpretation of mortality statistics, I employ the method of stating typhoid deaths as so many per 100,000 inhabitants..

In my belief that is the more correct method to employ, and it is a very generally employed method. I have at times seen another method employed, and I do not believe that it is a feasible one, namely, the percentage of typhoid deaths to total deaths. The reason I do not approve of that method is because, to illustrate, Chicago might have this month much more typhoid than last month, but the total death rate because of some disaster like the Iroquois Theater fire would run up the total deaths so that the typhoid death would apparently improve, whereas really it was worse.

that such typhoid bacilli would reach a point in Lake Michigan opposite the city of Chicago?

A. With the assumptions you make I can not answer otherwise than that they would, but it is hydrographically impossible for such a current to flow from Milwaukee to Chicago intake,

because the water in the lake does not move near the
7026 shores in a parallel direction to those shores. There

are cycloidal motions and the water passing the Milwaukee sewage outlet would be so dispersed, even though the winds were favorable to a general southern current, that the particular water from the Milwaukee outfalls would not reach the Chicago intake for, to make a rough guess, weeks and possibly months.

When I had the charts prepared which were introduced in this case by me as a schematic representation of the self-purification of waters, etc., the best information that I was familiar with, regarding the longevity of the typhoid bacillus was that contained in the reports of the Massachusetts State

Board of Health.

7027 Since having been engaged on the case I have become ac-

quainted with similar investigations which have recently been made by witnesses in this case, which information is much more exact and practicable and in accordance with actual facts, in my opinion, than the Massachusetts experiments. Had I asked this diagram or this chart to be prepared later I should have used the latter and better information contained in the recent testimony in this case.

As to the longevity of the typhoid bacillus, my opinion is that, particularly with reference to this case, the experiments made by Doctors Russell, Jordan and Zeit would guide my

opinion on this question.

7029 Q. Mr. Hering, is there any instance in your whole

career as a sanitary engineer, or an instance coming under your observation as to the work of other reputable sanitary engineers or sanitary scientists where the water in a running

stream has been recommended as free from the typhoid bacilli of a large and populous city existing on that watershed with a stream velocity of from 10 to 20 days?

A. Without filtration I do not know of any case exactly answering your description.

7031 There are artificial filtration plants in existence which remove 100 per cent of the bacterial contents in the water. I remember seeing those in Europe and I believe also a few weeks ago in Philadelphia.

Q. Assuming, Mr. Hering, that the dejecta from the typhoid patients which ordinarily exists from one end of

7035 the year to the other from a city containing a population of 13,000 people, be deposited in the Mississippi river immediately above the city of St. Louis, that prior to the existence of this discharge a recommendation had been made to construct a filtration plant at the city of St. Louis at the Chain of Rocks, this dejecta being deposited in said stream 38 miles above the Chain of Rocks, if it were possible to do so, would you not change your recommendation and recommend the establishment of the filtration plant above the place or point of discharge of the dejecta from the typhoid patients above stated?

A. Under the conditions you state I would not, and if I can now instance the case to which I had reference a moment ago I will say that two large cities, adjoining each other so that you do not know when you pass from one to the other, and both cities situated on one of the largest rivers of Europe, near its mouth, both discharged all their sewage into this stream, the upper one, which is Hamburg, having a population of one million, or thereabouts, both cities on this tidal stream where the sewage of the lower city, Altona, is likely to reach Hamburg and the sewage of the upper city, Hamburg, is likely to reach Altona. In both cities the water supply is filtered and with excellent results, and under those conditions being well familiar with both cities for many years I would not, if I had an oppor-

tunity to do so, recommend any other method of water supply than the river water after it has been filtered.

As a sanitary engineer and taking into consideration what I could learn from others regarding the question of effect, I would state that if a city of 13,000 population were to be situated upon the Mississippi immediately above the city of St. Louis, it would make no dieffrence with me, in my recommendation regarding the filter plant to be constructed for St. Louis. Irrespective of the filter, I would say that presumably the more infection contained in the water, the less wholesome it
7037 would be as a self-evident proposition.
7039 In making the recommendation as to the construction of the canal, the following was taken into consideration:

The discharge into the Illinois river in the first place assured a positive removal of the sewage from Lake Michigan, the only possible source of Chicago's water supply, and the dilution which was recommended was so large that no objectionable results could be seen. The greater economy of this project and the incidental value of the works, as a navigable waterway between the lakes and the Mississippi river, made the project, while safer from a sanitary point of view, also less expensive from a financial point of view, and of greater advantage from a commercial point of view.

7042 The result of this whole transaction is that by the opening of the canal, the city of Chicago has avoided the deposits of organic matter coming from the sewers of Chicago, and manufacturing waste in the city of Chicago, in the Chicago river, and while such matters are not now deposited in the Chicago river, they are carried by the waters of Lake Michigan out of the river into the canal and thence into the Desplaines and the Illinois river.

Q. Is there any validity to the assumption that a city of 13,000 inhabitants exi sts upon the Mississippi river immediate-

ly above St. Louis, based upon the chart which you have introduced in evidence?

7043 A. The information which the chart was intended to convey in my opinion, was the relative amount of infection that would be contained in the three rivers upon reaching St. Louis, irrespective of any population residing immediately above St. Louis.

7044 PROFESSOR GEORGE DOCK, Examined in chief by Mr. Todd.

I am a physician and teacher of medicine, and have the chair of Theory and Practice of Medicine in the University of Michigan. Have been connected with the University of Michigan for thirteen years. Graduated at the University of Pennsylvania in 1884.

7044 The next year I spent in a hospital in Philadelphia, St. Mary's Hospital in the worst typhoid fever district of Philadelphia, in Kensington, Philadelphia, where I saw a good deal of typhoid fever and I spent a year at that.

After that I went to Germany, to prosecute my studies in medicine, internal medicine, especially; I went to Leipsic at that time, which was very full of typhoid fever. My experience in Philadelphia, where I expected to settle, had increased my interest in the disease and I paid a great deal of attention to typhoid there. That was before they had improved the

7045 water supply and sewage of Leipsic, and there was a great deal there. I spent part of the year there, then I went to Berlin and saw a great deal of typhoid fever there. I studied the bacteriology of it in both those places and spent altogether two years over there, in the study of pathology and internal medicine.

I then went back to Philadelphia, where I was assistant to Dr. Osler and Dr. Musser, in the University Hospital. I saw a great many cases of typhoid fever and there I began the study of malaria. Dr. Osler was then the first man in America, study-

ing malaria. He had a great many cases brought in to him from the outside. I spent a great deal of time working on them and became very much interested in the practical diagnosis of malarial disease.

After that I had an offer to go down to Galveston, Texas, to teach medicine and pathology. I went there chiefly on account of my interest in malaria. I went down there and stayed three years. I was a professor of pathology in the Galveston Medical school and physician to the Hospital connected with the medical school and the last two years I was there, practiced. In Galveston I found they were diagnosing practically no typhoid fever at all and yet I saw lots of typhoid fever patients there. I was able to see that cases that were diagnosed as malaria and typho-malaria were typhoid fever, and my experience showed me that none of these cases had malaria. I did, however, see fatal cases of malaria. They were all cases that either came from the Tropics, Nicaraugua, or Panama, or else cases from the interior of Texas, where they occassionally have
7046 very severe forms of malaria. I became very much interested in the practical diagnosis of so-called malarial diseases, continued malaria, and various local names that are given to this disease, and did some work on it, wrote an article and read a good many papers on the subject before medical societies. On one occasion I made an offer to visit any patient having typho-malaria or continued malaria, and examine the blood free, in order to settle whether it was malarial fever or could be diagnosed as typhoid. I never had occasion to have my offer accepted. While in Texas, I studied the characteristics of malarial fever as they obtained in the southwestern part of the country. I saw many cases and examined them all very thoroughly, wrote several papers on the subject that have been widely quoted, and became looked upon as somewhat of an expert in malarial diseases. Then I went to Ann Arbor, and there I had same experience I had in the south. I found that the doctors were diagnosing many cases of typho-malarial fever.

My interest, of course, was still alive. I examined many of the cases postmortem as well as in life, and I was able to show the same thing, cases that were diagnosed as typho-malarial and continued malarial were all cases of typhoid fever. In Michigan I did not see any fatal cases of malaria at all. Since then I have examined a great many cases every year. I have cases sent in under the diagnosis of typho-malaria or some similar name and I have frequent occassion to clear up the diagnosis. I have given much study and thought to the question of malaria in St. Louis and the Mississippi Valley.

7048 (Witness reads extracts from article written by Dr. Bremer, a St. Louis physician, in the Medical Review for August, 1895. This extract, among other things, contains the following:) "Physicians are apt even today to look upon many ailments as due to malaria, which in reality have nothing to do with this disease either directly or indirectly. This means St. Louis and environments in particular, and the Mississippi valley in general, but it probably applies to the whole United States. Periodic chills, followed by high temperatures, which mark the initial stages of so many cases, are generally interpreted as due to malaria, hence the erroneous and mischievous diagnosis of malaria, remittent fever or typho-malaria, under which so many cases of typhoid figure in the reports of our city Boards of Health.

7049 I have come to the conclusion that in St. Louis, at least, malaria is an extremely rare disease. Four years ago I went to the City Hospital for a number of months in the hope of finding a good plasmodium infected subject. My efforts were unsuccessful for a long time. The cases pointed out to me by attending physicians as malaria and treated as such, proved to be infections which had nothing in common with that disease."

In 1898 I was asked by Surgeon General Sternberg, of the United States Army, to visit certain army camps in order to examine the blood of patients diagnosed largely as malaria. Out of

in the water of the Illinois and Michigan canal, after the water had entered the Illinois river, had fixed a unit of measure which, from a sanitary point of view, he considered sufficient to obviate any subsequent injury to the State of Illinois on below. This measure was a flow of water equal to 180 cubic feet per minute for every thousand persons draining in the river at Chicago.

Examinations which I made with reference to the Blackstone river in Massachusets, which is quite foul at its upper end, and receives much additional sewage on its way, resulted in my conclusion that after a flow of about 140 cubic feet per thousand persons was observed in the river, the character of the water had become entirely inoffensive.

Similar investigations were made from the results obtained in the river Seine, receiving the sewage of Paris, France. The sewage there does not include fecal matter, because this is otherwise removed. It was found on the Seine that where the dilution was 60 cubic feet per thousand people, and after a flow of 14 miles, the river was considered unobjectionable to sight or smell.

Also some German rivers were considered, the Elbe and the Ober, and similar data were secured.

The result from these and still other investigations made me conclude that for the Chicago sewage canal there should be a recommendation that the size is sufficient to carry water at the rate of 240 cubic feet per second for each thousand persons, as stated in the preliminary report.

6993 A disposal of the sewage by dilution is still very common and it must remain so for a long time. Over in Europe we find cities situated on the large rivers discharging their sewage into them with entire impunity. The city of Hamburg discharges its sewage into the Elbe, which is a tidal

6994 stream at this point. The adjoining city of Altona does the same and both cities take their water supply from this stream, receiving the sewage of over 1,000,000 of people but both cities carefully filter it. (Witness reads in evidence

table compiled from information secured by the Massachusetts State Board of Health in investigation made, as shown by report for 1890.) This table is based on a flow of water in cubic feet per second per 1,000 persons and chemical constituents of sewage in parts per 100,000. Table is reproduced on page 6995.

6996 Two lines have been drawn across this table. Above the upper one conditions are indicated where the dilution is practically in all cases offensive. Below the lower one the dilution has never been found to give offense. These two lines are indicated by a dilution of sewage from 2 1-2 cubic feet per second per thousand persons to 7 cubic feet per thousand persons.

It is the duty of the engineer to select between these limits that dilution which conforms to the local conditions of the problem.

In considering this question of dilution for the drainage canal, I adopted the standard of 4 cubic feet per second per thousand persons because in the state of knowledge at that time I did not feel justified in recommending a less dilution. Subsequently, I understand, the number was reduced to 3 1-3 cubic feet per thousand persons, and on that basis the canal was constructed. The dimensions were not altered but it was considered that a larger population than one which I had figured on would be served by this canal by assuming a less dilution.

I believe that the dilution which it is intended to give the water at all times is sufficient to prevent offensiveness and in view of what I have said above also improve conditions below.

I have prepared a table of dilution based on population and flow for 1900, 1901 and 1902 for the drainage canal, which is reproduced on page 6997.

6998 The table indicates that the mean discharge during each of the three years was above the line which limits the offensive dilution, therefore, indicating that there should be no offense.

7000 In considering the several possible ways of disposing of the sewage of Chicago from present knowledge and experience my recommendation today would be that the sewage of Chicago should be disposed of by dilution through a channel substantially like that which has been constructed with a subsequent discharge into the Des Plaines and Illinois rivers.

7001 Chart showing the comparative pollutions of the Illinois, Mississippi and Missouri rivers and profiles of said rivers.

7003 The conclusions of the chart as indicated by the ordinate at St. Louis is that the relative proportion of typhoid bacilli arriving at St. Louis from the populations situated on the Illinois, the Missouri and the Mississippi rivers, between the limits of Chicago, Omaha and Minneapolis, are about as 13 to 96 to 107, respectively. These figures are merely the proportions. They indicate the relative frequency of the still virulent typhoid bacilli at St. Louis, arriving there from various cities on these three rivers, based on the population of the cities and also based on the examinations made by Hiram F. Mills as to the longevity of the typhoid bacilli.

I consider that the Mississippi river in its raw condition was not a fit supply for drinking water for any modern community prior to January, 1900. The same as to the Illinois river at Grafton and the Missouri river at its mouth. The Missouri river today is not a safe drinking water in its raw state. Same as to the Mississippi river above Grafton and the Illinois river at Grafton. According to the present views on water supplies held by engineers and sanitarians, the water of the Mississippi at the Chain of Rocks in its raw state or as treated in the settling basins at St. Louis is not a safe drinking water. That water should be artificially purified by filtration. I have read the report made by a commission of hydraulic engineers upon the water supply of St. Louis, to the Mayor of the city, in 1902. This commission consisted of Mr. Benezette Williams, Geo. Y. Wisner and Allen Hazen. My associate,

Mr. Geo. W. Fuller, was asked to consider some features, and he made a report which is added to the report of the commission. I have read the report of Mr. Fuller that is published in the document to which I refer in regard to the question of filtering the water of St. Louis, as advocated by Mr. Hazen in that report. My personal views are that this water, in order to be supplied to the city of St. Louis for domestic consumption should be purified by mechanical or rapid filtration as the best, most rational and least expensive method of purifying this particular water. In my opinion it would make no practical difference in the construction method or cost, nor in the method and cost of operation, to filter the water of the Mississippi river, at the Chain of Rocks, which consists of the combined waters of the Illinois, Mississippi and Missouri rivers, with the sewage of Chicago emptying into the drainage canal, than it would if such sewage was eliminated from the sanitary drainage canal.

7007 The data which I have introduced in evidence would indicate to me that first and foremost a filtration of the water was necessary, due to the probability that typhoid bacilli would reach St. Louis to a large extent from the Mississippi and Missouri and to a less extent from the Illinois river. I should give no consideration at all to the sewage coming from Chicago because it is a small factor in the problem. It is too small a factor in the problem to materially affect any recommendation. The operation of such a filter plant would not require a higher degree of skill or more expensive men, with the sewage of Chicago emptying into the Illinois river than it would if such sewage was not present. (Witness temporarily withdrawn.)

7008 ALBERT S. CRANE, Examined in chief by Mr. Todd. Am civil engineer. Graduated from Cornell and spent the summer of 1891 with Mr. Hering in Europe, visiting sewage purification and water filtration works principally. (States educational qualifications.) I have been principal assistant

engineer of the sanitary district of Chicago since March, 1900.

7009 I prepared the chart introduced in evidence by Mr. Hering representing the self purification of the waters of the Missouri, Mississippi and Illinois rivers between the cities indicated, based upon the longevity of the typhoid bacillus, etc. (Witness states in detail the sources from which he secured the information on which this chart is based and the facts relating to the method of constructing the chart.)

7011 Chart showing approximate discharge curves based on discharge measurements made by the Mississippi River Commission from 1838 to 1898. This chart is reproduced on page 7011 and shows that the Illinois river has the effect of a city of 13,000 situated immediately above St. Louis, the Missouri river of a city of 96,000 and the Mississippi river of a city of 107,000, or a relationship of 13 to 96 and 107.

CROSS-EXAMINATION, By Mr. Jeffries.

(Witness gives list of cities on the various rivers which he took into consideration in making such chart and where he obtained the velocity of the waters and flow, etc.)

7016 Assuming that the time flow from the mouth of the south fork of the Chicago river to the city of St. Louis was 10 days, the Illinois river would have the effect of a town of about 160,000 population.

7018 RE-DIRECT EXAMINATION, By Mr. Todd.

If at maximum flood time, the distance in time from Kansas City was 3 days instead of 6.8 as shown by this chart, the effect would be similar to that of a city of 230,000 directly above St. Louis.

7020 RUDOLUH HERING, Resumed the stand for cross-examination by Mr. Jeffries.

When I made my report in 1887 I reported upon nothing except methods with respect to the disposal of the sewage of

Chicago and the ultimate protection of the water supply of Chicago.

7022 As a sanitary engineer, it was necessary for me to take into consideration the fact that the discharge of sewage of Chicago into the Chicago river and thence into Lake Michigan, was a menace and danger and a detriment to the water supply and to the public health of the city of Chicago at the time this report was made by me.

7023 In my observations made of conditions existing in Lake Michigan at the time this report was made with reference to the sanitary condition of the water in Lake Michigan at Chicago, I took into consideration the fact that the organic matter contained in the Chicago river and which remained therein for weeks and months between the freshets, contained substances objectionable to the water supply and deleterious to the public health.

7024 There is a current in Lake Michigan along the west shore near the city of Chicago, almost all the time. The crib caretaker, who is located out in the lake, was of the opinion that the currents were about evenly divided during the year north and south, depending upon the direction of the wind. This current was as much as a mile and a half, but of course, generally less. If the current was 2 ft. per second,—the distance from Chicago to Milwaukee being ninety miles—the water in the lake would require seventy hours or three days to flow from Milwaukee to Chicago.

7025 I do not admit this is a possible condition, because I never knew that this current had such a rate and that such a rate would be maintained substantially or constantly for three days.

Q. Assuming that typhoid bacilli are discharged into Lake Michigan from the sewers of Milwaukee, and assuming that there is a current flowing past the city of Milwaukee to the south, with the velocity of 2 ft. per second, which velocity is maintained for a period of three or four days, is it not a fact

circumstances, however, a man in examining the charts would have some little trouble in following the oblique lines, and direct comparison would not be so easy.

6971 Referring to the chart which I introduced in evidence showing the comparative results of the colon tests as made by Prof. Jordan for 1901, it is true that on that chart, taking the 1 cc. determination, the water in the Illinois river at Grafton shows a greater pollution than the water in the Mississippi river at St. Louis, the Missouri river at Bellefontaine and the Mississippi river at Grafton. It is also true that some of these percentages are the result of a less number of determinations than others.

6973 Assuming nothing unusual in the death rate, there would be no particular difference between the method called the percentage of mortality system and the numbers per 100,000, in determining the typhoid and other death rates in cities, but it would be possible to have very misleading results. For that reason I do not use the mortality percentage. (Witness is asked hypothetical question as to the application of these two methods to the conditions stated therein, and in reply, states:)

6974 Basing my reply on the numerical data submitted in the question, it is my opinion that there is no material difference between the two methods of stating the result. Scientists have thus far been able to determine the longevity of pathogenic germs only within roughly accurate limits.

6975 RUDOLPH HERING, Examined in chief by Mr. Todd. I am a hydraulic and sanitary engineer and reside in New York. The firm is Rudolph Hering & George W. Fuller, who testified in this case. (Witness states educational qualifications.) I am not a chemist or bacteriologist. I en-

6978 deavor to keep posted on the progress made in both sciences so far as they relate to the sanitary condition of the water, and then I take the results obtained by those men in whom I have every confidence and whose ability is unquestioned.

My attention was first called to the sanitary problems of Chicago in March, 1886, when I received a telegram from the Mayor of Chicago to make him a visit and spend a day, so that he could talk with me. I came to Chicago and was engaged as Chief Engineer of the Drainage and Water Supply Commission. As Chief Engineer to look into the sanitary prob-

6979 lems of Chicago, I made whatever investigations I thought were necessary to answer the resolutions passed by the Mayor and the City Council of the city with reference to obtaining "pure water and scientific drainage." In January, 1887, I made a preliminary report, giving the general conclusions which had been reached up to that time. (Witness reads that part of the preliminary report prepared by him, which applies to the sanitary problems of Chicago, which he has under consideration, this report being dated January, 1887.) This report contains the description of the conditions existing in Chicago at the time of examination and the discussion of three methods of disposing of Chicago's sewage, one of which is by means of the drainage canal. The report concludes by recommending the drainage canal project and is signed by Rudolph Hering, Chief Engineer, Benezette Williams and S. G. Artingstall, as consulting engineers.

6991 Subsequent to the preliminary report, the legislature of the State in 1889 passed a law for the construction of the sanitary district of Illinois. In arriving at the conclusion that the drainage canal was the proper solution of the sanitary problem in Chicago, I studied all the facts to be found in Europe and America. There had been a number of cases of sewage discharged into water courses carefully observed in Europe and in the East as well as at Chicago. This information was carefully collected, weighed and laid the foundation for the recommendation which fixed the size of the proposed channel.

6992 Among other things I found that Dr. John Rauch, Secretary of the State Board of Health of Illinois, who had been making very careful investigations of the gradual change

sequent 36.5, and that the difference between these averages was 15.45, in figuring out the percentages by dividing 15.45 by 21.05 gives a percentage of practically 73 per cent, does that 73 per cent in your opinion, figured upon the basis that I have indicated in arriving at it, express a large increase in typhoid fever?

7078 A. No, but I should say that I consider your method of getting at the result, very faulty. For example, the increase did not occur in a single year, but spread over a series of years, and it is not a figure that varies, up and down in those years, but goes up steadily. If the 73 per cent had occurred between 1899 and 1900, I should say that either there must have been a new focus of infection, or else that the old focus must have been extremely badly handled but as it is spread over four years, and the ascent is gradual, and really began a year before the point of deviation, I still adhere to my former statement that it is not a great increase.

I understand that the figures I am now testifying to, are figures based on the estimation that the typhoid fever death rate, as reported in the house statistics, and estimated, do not include the other heading of typhoid fever. In figuring out the percentage of increase, the average does not give us as correct an idea as to the relationship existing between each year. The percentage of increase from 1898 to 1899 is 34.7; from 1899 to 1900, 25.3; from 1900 to 1901, 14.7; from 1901 to 1902, 9.5; from 1902 to 1903, 26.7. This percentage of increase shows that the first year has the greater increase over the previous year.

7079 RE-CROSS-EXAMINATION, By Mr. Jeffries.

Q. Taking the number of typhoid deaths per 100,000 population for 1897, at 23.4, as the highest number reported during any one of the four years immediately prior to 1900, compared with the average number of deaths for 100,000, for the four succeeding years, 1900, 1901-2 and 3, please state the percentage of increase or decrease?

7080 A. I get an increase of 55.99 per cent.

Q. What is the percentage of increase or decrease for the number of deaths reported per 100,000 population for the highest year during the period of 1896 to 1899 inclusive, and from 1900 to 1903, inclusive?

A. 98 per cent increase.

Q. Now, what years did you employ in that calculation?

A. The years 1897 and 1903.

Q. I will ask you if the result shown on this table for the four years from 1896 to 1899, does not show that there was an alternate increase and decrease year by year in this to wit, 1896, 20.2; 1897, 23.4; 1898, 17.3; 1899, 23.3, and that since 1899, to wit, the years 1900 to 1903 inclusive, there has been a continual increase?

A. That is right.

Southern Hotel, St. Louis, Mo. Oct. 24, 1903.

7082 LEWELLYS F. PARKER, Examined in chief by Mr. Todd.

Reside in Chicago. Am Professor in the University of Chicago. (Gives educational qualifications.) Am Professor in the medical faculty of the University of Illinois. Have been Professor of pathology, bacteriology and anatomy. Was sent by the Johns Hopkins University to study an epidemic of cerebral spinal meningitis in Maryland and in 1899, Dr. Flexner and myself were sent as special commissioners to study the tropical diseases in the Philippine Islands, and incidentally to study the epidemic of plague and beri beri in Hong Kong, India and Japan.

7085 In Manila there was abundant opportunity for the study of the three diseases very prevalent in the Island, namely, typhoid fever, malaria and the acute tropical dysentery, and we were able also to not only study a large number of cases of leprosy, but to make biological examinations and autopsies of a number of lepers dead in various stages of the disease. Well, in brief, through the courtesy of the Seugeon-General of the

Army and Navy we had access to all the army and naval hospitals, and also to the native hospitals and Spanish hospitals, and the studies were clinical, including microscopic and bacteriological studies, and when deaths occurred we made autopsical and bacteriological examinations.

7086 Nothing especially new came out of our study of typhoid in Manila. Was also appointed by the Secretary of the Treasury, in Washington, along with several other professors to investigate the disease prevalent in San Francisco among the Chinese.

7087 In Baltimore, I studied the typhoid epidemics and malaria and had an opportunity there to become very familiar with both diseases. There seemed to be no doubt, from observation of the conditions, that the water supply of Baltimore is a polluted supply, and that at any rate, a majority of the cases of infection were water-borne. Doubtless some of

7088 the cases were cases of so-called secondary infection of typhoid from contact or from environment of food stuffs. (Witness states cause or causes of typhoid fever.) It seems extremely probable that some of the more localized groups of cases in the city of Chicago, have been due to infection by flies. The studies of Dr. Alice Hamilton point in that direction.

7090 Remittent fever, intermittent fever, typho-malarial fever, congestive fever and simple continued fever are all clinical rather than pathological terms, and date back to the time when classifications had to be made on symptomology rather than upon pathology and teiology.

The remittent fever was the term given to a fever which had exascerbations and declines without reaching the normal, as a rule. and intermittent was the term given where the temperature went up high and came down to the normal, then up high again and down to normal.

Typho-malarial fever was a term given to cases which were believed to be by many, a fever distinct from typhoid, and dis-

tinct from malaria, a fever which ran the course of typhoid, but which had many symptoms resembling those of malaria while congestive fever was a very vague term used in different ways by different clinicians and was usually associated with the idea of congestion of the head, rush of blood to the head, along with the fever, while simple continued fever was a term applied by, as a rule, the less well-educated physicians, to mild forms of fever running over a considerable period, generally over more than ten days or two weeks. It was a term used by people who believed that such fevers were not typhoid and not malaria, but simply continued fever. They didn't know exactly what it meant. Now all of those terms are given up by good clinicians at the present time; there is no such thing as a remittent fever as a clinical entity any more. It is either typhoid or malaria, or acute tuberculosis, or some other infection, and usually it is possible during life to determine that a case of so-called remittent fever, or intermittent fever in the same way, may be one of several diseases perhaps. Most often what is designated intermittent fever is malarial fever, but cases of typhoid fever are often mistakenly designated as malaria, intermittent, etc. The congestive fever might be one of various things; sometimes it is typhoid and sometimes it is malaria. Sometimes it is something else.

7091 Simple continued fever may be typhoid. I think perhaps most often it is a mild case of typhoid fever. It may be something else. None of those terms would be used now by a skilled clinician.

I have the statistics of deaths from remittent, etc. fevers, in St. Louis, for the years 1890 to 1902, and also the deaths from typhoid fever alone for the same period; also the same figures for the city of Baltimore. (These figures are given on pages 7092-3.)

7094 From what I have said, it is clear that, in my opinion, the cases reported as remittent, etc. are nearly all cases of something else, mostly typhoid, that could be diagnosed by

skillful physicians. In fact, I think the addition of the two columns, the typhoid column and the remittent, intermittent, typho-malarial, congestive and simple continued fevers, would give a truer typhoid death rate in the city of St. Louis, than any other of the statistics that we could get.

7096 In view of all the facts that I have related, it is absolutely certain that if these statistics are absolutely reliable that there has been no increase of typhoid fever in the years 1900 and 1902 inclusive, as compared with the ten preceding years in the city of St. Louis.

The statistics show that the total number of deaths reported from typhoid and the remittent group together, run along at a tolerably constant figure. The figures, however, show in the typhoid fever column alone an increase in the number of typhoid cases; quite a marked increase during the last three years, from 1900 to 1902. They also show quite a marked diminution in the remittent and intermittent group during the last three years. There has evidently been simply a transfer from the remittent column to the typhoid fever column. In other words, typhoid fever has been diagnosed more often during the last three years, than it has in the last preceeding years. There has been no greater number of cases, but the diagnosis appears to have been better. That the diagnosis is not yet good by many of the physicians in St. Louis is obvious from the large number of cases still reported in the remittent group.

7098 If a specific circular had been sent out by the Board of Health in the latter part of 1899, calling particular attention to typhoid conditions existing in that city, I think it would have influence on the reports made to the Board of Health. (Witness gives reasons for his answer.)

7099 The death rate from typhoid fever in St. Louis, as I interpret the vital statistics, is not excessive, as compared with Baltimore and corresponding cities. If one takes the extreme statement of one investigator, the maximum distance that contagion of typhoid fever has been shown to travel in a flow-

ing stream, is about 70 or 75 miles. That view and assertion have not met with general acceptance, however. Am acquainted with the general conditions which obtain in Chicago, the drainage canal, the Illinois river, the Mississippi and Missouri rivers down to St. Louis. In my opinion a typhoid bacillus lying in the sediment of a stream for a period in excess of sixty days, would be harmless. In my opinion, pathogenic bacteria in the sewage of Chicago would not be able to survive the journey from Chicago to the intake tower, at St. Louis, and be a menace and danger to the inhabitants of St. Louis. In my opinion, typhoid bacilli could not survive that same journey taking into consideration the sewage discharged at Peoria and Pekin, etc. into the river. In my opinion, the sewage entering the drainage canal, which empties into the Illinois river and thence into the Mississippi, would not be a menace and danger to the inhabitants of the State of Missouri and the citizens of St. Louis, taking their water supply from the intake tower at the Chain of Rocks. Assuming an epidemic of Asiatic cholera in Chicago, the germ would not survive the journey from Chicago to the intake tower at St. Louis. The introduction of this mass of organic material from the stockyards and distilleries of Peoria would favor the disappearance of the typhoid bacillus.

7103 There would be no danger of infection by tetanus or enteriditus sporogones. As to the statistics referred to, I can seen no connection between the opening of the drainage canal and the figures. The probable length of life of the typhoid bacillus introduced by way of the drainage canal into a sluggish river, such as the Illinois river, flowing through a more or less densely populated country, and receiving successive increments of organic matter together with the associated saprophytic bacteria, I should think would be from five to seven days.

7104 (Witness is asked hypothetical question, assuming typhoid deaths in various cities on the water shed of the Mississippi, and assuming that the typhoid condition in St.

Louis in 1900, is due to a contaminated drinking water, in large part, and is asked as to whether, under such circumstances, the typhoid fever in St. Louis, could be attributed to the sewage of Chicago, to which witness replies that in his opinion, it could not.)

7105 Table showing death report from typhoid fever in cities lying tributary to the Missouri.

7106 Same as to Illinois river, exclusive of Chicago.

7107 Table showing total number of deaths from typhoid fever in cities lying tributary to the Missouri, Mississippi and Illinois rivers respectfully, and also table showing deaths in Chicago and St. Louis. Taking into consideration the above tables, in my opinion the probability of infection or pol-

7108 lution of the water supply of St. Louis, would be largest from those places within the mean flow of five to seven days. I don't know how to express that—from those places where the average flow or the mean flow is within five to seven days of St. Louis. I think the probability of infection or pollution from the great distances requiring more than twelve days for example, would be remote.

CROSS-EXAMINATION, by Mr. Jeffries:

7110 Typhoid fever is epidemic in Baltimore nearly every year. The water supply is believed to be responsible for it. There are different parts of the city which get different water supplies. The part that I was interested in particularly, came from Lake Roland. That lake is, I should think, five or seven miles from Baltimore.

7111 It was my opinion that the cases of typhoid fever occurring among those who drank of the water from that district, from that water supply, were due to the pollution of the water supply by typhoid bacilli.

7112 I am of the opinion that that could have been responsible for the epidemic.

7115 In determining the condition of a certain body of water, if I found, or if any one found a large number of bacilli of the colon group, for example, that would be evidence—other things being equal—of probable sewage contamination.

7116 I had, while house officer in the Toronto general hospital, a considerable experience with typhoid cases. There was a large epidemic that year, larger than usual, but I had nothing to do with the actual source or cause of the epidemic.

7117 It was supposed I believe it was definitely proven but I am not sure, that there was a leak in the intake pipe. The pipe went out to an island, it passed through Toronto Bay, and they found out afterwards that there was a hole in the pipe, going across the bay, and that the real sewage mixed water was taken directly into the water supply of the city.

7119 In order to be absolutely safe, the city of Toronto ought to go out about 100 miles. That would be past the middle of the lake, wouldn't it? I don't know how broad the lake is. The object in extending the water mains out in the lake, would be to diminish amount of pollution in the water.

7120 Do not understand me to say that I would recommend putting a pipe out 100 miles. There is a much easier way of getting a water supply than that, but if you tried to get it in that way, assuming an impossible condition, that would be the purest water that you could get, I should say, into the middle of the lake, farthest from the shore would be the place to draw your water in case you had to get it from the lake.

It would be much better to put in a sand filtration, and then take it from anywhere, provided you could educate the people there to conduct such a filtration plant in the proper way.

I think the water would undoubtedly be polluted for quite a distance out if typhoid fever were occurring in the city.

Q. And that was your object in saying that you would extend the main 100 miles out?

400 patients in the Sternberg hospital, practically all of whom had a diagnoses of malaria in one form or another, under some other name such as bilious remittent, typho-malarial, etc., I found only one case that was malarial fever. The same conditions were found at Camp Mead, Penna., and at Knoxville I was not able to find any malarial cases. Even in Michigan, I still see physicians who are giving wrong diagnoses for typhoid fever. I have made a special and persistent study of typhoid fever for about 20 years. I have also made a special study of the so-called germ diseases. (Witness gives clinical diagnosis of typhoid fever, intermittent fever, remittent fever, typho-malarial fever, congestive fever and simple continued fever.) Remittent, intermittent, typho-malarial, congestive and simple continued fevers are not distinct types of disease and usually all such names are included, by careful Boards of Health, under the head of typhoid fever. The symptoms of typhoid fever sometimes rather closely simulate the symptoms characterized under these headings, especially if one is not particularly
7053 educated on the finer diagnostic points. An examination of the blood of the malarial organs, on one hand, or the typhoid reaction on the other, usually clears them up very quickly, but, to a casual glance, the diseases may be very much alike.

Q. Assume that the number of deaths reported as occuring from typhoid fever in the city of St. Louis as evidenced by the annual report of the Board of Health of the city of St. Louis Health department is as follows:

| | |
|---|---|
| 1890 | 140 |
| 1891 | 165 |
| 1892 | 441 |
| 1893 | 215 |
| 1894 | 171 |
| 1895 | 107 |
| 1896 | 106 |
| 1897 | 125 |

| | |
|---|---|
| 1898 | 95 |
| 1899 | 131 |
| 1900 | 168 |
| 1901 | 198 |
| 1902 | 222 |
| 1903 | 288 |

7054 Assuming that the number of deaths for the respective years correctly represent the typhoid condition in St. Louis, my opinion is that these figures show an increase in typhoid fever in the city of St. Louis during the last ten years. I should say there has been an increase but not a great increase. I am particularly struck by the increase since 1898, because in 1898 the doctors all over the country had their attention very strongly called to the wrong diagnoses that were formerly made in the so-called typhoid diseases and the attention of the public has been very strongly called to it.

7055 Assuming the statistics in the foregoing question as above indicated and assuming further that the number of deaths reported in the same reports under the headings remittent, intermittent, typho-malarial, congestive and simple continued fevers is as follows:

| | |
|---|---|
| 1890 | 226 |
| 1891 | 296 |
| 1892 | 326 |
| 1893 | 284 |
| 1894 | 179 |
| 1895 | 155 |
| 1896 | 177 |
| 1897 | 172 |
| 1898 | 134 |
| 1899 | 148 |
| 1900 | 112 |
| 1901 | 80 |
| 1902 | 102 |
| 1903 | 91 |

The number of deaths reported occurring from typhoid fever alone in the city of St. Louis, do not properly represent in my opinion the total number of deaths actually occurring in that city during the period in question.

7056 A. The most important reason is that the death rate from malarial diseases is altogether too high, too high for every year. Take an exceptional year for typhoid, when there was an accidental condition, the malaria there is 50 per cent higher than it was two years before. In 1890 there were 226 cases of the malarial disease. I include all these various diseases in malaria. In 1892 there were 326. Now, from studying malaria very carefully at that time, I say there was no reason why malaria should increase in a city like St. Louis to that extent at that time. The death rate in every year is altogether too high in a city like St. Louis. It is higher than I believe possible.

(Witness describes malarial fever and the distinct types of same.)

7057 The type of malaria that is common in the central states on the Mississippi river, is the intermittent form, which is practically never considered a fatal type of fever. Nobody ever dies of it unless he has had some previously exhausting disease. The failure of the statistics assumed in the foregoing hypothetical questions, to properly disclose the number of typhoid fever deaths occuring in St. Louis, I attribute to the use of the term "malarial fever, typho-malarial fever," etc., applied to certain cases of typhoid fever.

7058 The only city that I know of where the death rate from malarial fever alone is as high as in St. Louis, is New Orleans. A study of the table introduced by Prof. Jordan will be enough to show that the whole malaria statistics of that town are seriously faulty. If we add the totals of the table for typhoid fever and the table for remittent, etc. fevers, as they appear in the report of the Board of Health of St. Louis, and if we take those tables as indicating the correct typhoid fever

mortality in St. Louis, they do not indicate a marked increase.

7059 From the statistics that have been furnished, and from my experience in the diagnosis of typhoid fever, and typho-malarial fever, I should say it would be impossible to say exactly how many cases, but anywhere between 50 and 90 per cent of the so-called malaria ought to be called typhoid. At least 50 and probably as many as 90.

The board of health of Michigan, for instance, orders that all typho-malaria be classified under typhoid, and the new classification recommended by the United States census makes that same recommendation.

7062 The statistics do not indicate a marked increase, though they indicate a slight and gradual increase from the year 1898. An increase that I would explain partly from the fact that the diagnosis of typhoid fever has become broader all over the country. More cases are being included. There is a tendency everywhere to increase the proportion of typhoid cases in that way. There has been a slight and gradual increase.

There is nothing in the statistics as they appear to show any explanation of typhoid fever, as due to any particular cause. The increase for example is slightly more marked for the year 1901, but even there it is not at all striking. It is not such a thing as we find in the case of Butler, Penna., or the town of Ithaca. The sending out of letters by the Board of Health would explain the rise that has occurred in the last few years. Those letters manifest themselves in the typho-malarial column. My opinion is that when the two tables showing these mortality statistics, are taken separately, they do not correctly show the typhoid conditions, for the reason that the diagnosis of ma-

larial diseases were almost entirely erroneous and should have appeared largely under the head of typhoid.

7063 Doctors having their attention called by the notification, would report more cases as typhoid, and less as typho-malarial, than they had before.

7065 (Witness is asked to read table which is reproduced on page 7065 and to state whether in his opinion, based upon the tables heretofore read, typhoid fever has increased or decreased in St. Louis since 1900, and states:) The table does not show that there has been a marked increase; on the contrary, a slight increase. Such an increase as I would ascribe rather to increased care in diagnosis, rather than to any outside conditions.

7066 One of the most serious sources of typhoid fever are wells. Assuming that in April, 1895, the total number of wells in St. Louis, was 4,846, and that the city chemist after examining 59 wells condemned them as being unsanitary, and assuming further that in August, 1895, upon the report of the city chemist condemning seven more wells, the Board of Health passed a resolution that the city should make no further examination of the wells, and that since 1895 none of these wells have been condemned, my opinion is that if the water of these wells was used by the inhabitants for domestic and drinking purposes, it would be a very serious source of typhoid fever. My opinion is that the slight increase in typhoid fever in St. Louis indicates rather a change in the conditions of the city of St. Louis itself than in the main water supply, supposing that the main water supply comes from the river.

7067 A change in the condition of the river water is always indicated in such cases by a more marked increase. As to such an increase as we have here, it is altogether compatible with changing local conditions, such as wells, and the ordinary course of typhoid epidemics.

7068 Dr. Blickhahn wrote me from St. Louis while he was investigating malaria and conferred with me. After he had been working at the thing for about two years, he wrote me

that he had never been able to see a certain form of malarial organism, that is the so-called crescent. I was rather surprised at that, because I would have rather supposed, I would have thought that he would find crescents in St. Louis. Crescents are found in the more severe form of malarial fever. The severe types have these bodies associated with them. Blickhahn wrote me that he had not been able to find them and asked me to send him one of my specimens. I sent him some specimens that I had brought from Texas. I supposed he had simply overlooked them but he wrote back and said he had not seen them up to that time. That was additional evidence that severe forms did not occur frequently there, although of course they might occur now and then.

7069 That was during 1903 and 1904. In this country there are practically no fevers which produce death, which may be associated with typhoid fever. I mean to say that any disease that sets up any very great infection, in a large number of cases, is typhoid. There are in some other countries such fevers, typhus fever, for example, even that, at the present time, that we cannot distinguish quite positively from typhoid. Typhus fever does not give a Widal reaction. You do not get the typhoid germs out of the blood. That disease is very rare in this country and is only brought in, at long intervals, from Russia, nowadays. Sometimes from Ireland and sometimes from Mexico. It is a disease of extremely bad sanitation and poor food. It can hardly exist without those conditions, and this would prevent its spread or distribution through this country. The tables introduced show that there has been

7076 an increase in typhoid in St. Louis, even though you transfer all remittent, intermittent, etc. fevers into the typhoid column.

7077 RE-DIRECT-EXAMINATION, By Mr. Todd.

Q. Doctor, in figuring out the percentage of figures, assume that the average for 1895-6-7-8, of the percentages for the four years before 1900, was 21.05, and the four years sub-

7270 I know that they are present in the intestines of animals. I am not sure about particular animals; and they are present in the earth, in the soil, very widely distributed. If the germs of tetanus are prevalent in the intestines of animals, I know of no reason why those coming from the offal and washings of the stockyards and slaughterhouses of Chicago, discharged into the canal, might not be carried into the Illinois river and grow out into bacilli, under favorable conditions, if the proper temperature and the proper media were obtained, but tetanus is not a water-borne disease, as far as I know, in human beings.

7271 I have never known of a case of tetanus occurring from water-borne bacilli. By far the majority of cases are 4th of July cases, due to injury on the hand with a toy pistol and other cases, nearly all punctures by rusty nails of the bare feet. It is very improbable that a rusty nail could be moistened in water, drawn from the water supply, from a sprinkler, and a tetanus germ carried in that water. I do not think there is any evidence in favor of that theory.

7272 I haven't heard of the spores of anthrax or the germs thereof, being found in the Illinois river since the opening of the canal. I should be surprised if I should hear that, because when not in the spore form, the anthrax is the least resistant of any of the bacteria. I should not expect it to be found in spore condition because I think the spores would grow out into the less resistant bacilli, in the water.

7273 C. D. CASSINGHAM, examined in chief by Mr. Todd: I live at Wilmington, Illinois, and collected samples of water from the Kankakee river, in the years 1899 and 1900 for Prof. Long. (States where samples were collected, procedure, and method of shipment, etc.)

7277 FRANK L. STEVENS, examined in chief by Mr. Todd: I live at Raleigh, N. C. Am a teacher in the Agricultural-Chemical College of Raleigh. Before going there, I was in Europe, and prior to going to Europe, I attended the University of Chicago, where I worked under the supervision of Prof. Jor-

dan, in connection with the analyses of water. While in the laboratory, I received samples of water which came by express. (States how samples were received, etc.) W. G. Sacket assisted me there.

7279 CROSS-EXAMINATION, by Mr. Jeffries:

My work was purely chemical. (Witness states chemical constitutents that he looked for in the water.)

7281 WALTER GEORGE SACKETT, examined in chief by Mr. Todd:

Reside at Raleigh, N. C. Am teacher in the Baptist Female University. Prior to going there, I was in the University of Chicago and did work under Prof. Jordan, in connection with Streams Examination. (States how samples were received, etc.)

7287 (Stipulation that samples of water taken from the upper Kankakee, near South Bend, Indiana; from the upper Des Plaines river, near Libertyville; the Illinois river at Henry; the Mackinaw river at Cappa, and the upper Sangamon at Mahomet, were taken in the manner described by Prof. Long, as near as may be, and that the production of the witness, who took such samples, is waived.)

7288 THEOBALD SMITH, examined in chief by Mr. Todd:

Am professor in the Harvard Medical School and Pathologist of the State Board of Health of Massachusetts since 1895. Prior to that time, was bacteriologist in charge of the investigations in the Department of Agriculture at Washington upon infectious diseases of animals, and at the same time, professor in bacteriology in the Columbian University, Medical Department, Washington, D. C. (Witness gives experience in the line of investigations on the bacteriology of water.) Have published about 60 or 70 papers on the subject of bacteriology, not exclusively in relation to drinking water, but in relation to diseases generally.

7290 I have studied practically all the pathogenic bacteria that are accessible, except the plague bacillus.

7291 In view of the fact that our methods are still unsatisfactory in the isolation of the typhoid bacillus, at least not practicable on a large scale, the colon bacillus affords us the best indication of the possible presence of the typhoid bacillus.

7292 The typhoid bacillus is probably more perishable than the colon bacillus under a variety of conditions. The colon bacillus is a more vigorous organism than the more highly parasitis typhoid. The fermentation test is used universally in this country for the recognition of the colon bacillus. It is used at the chief test by the Massachusetts State Board of Health, in their filtration experiments. (Witness originated this test.) I first published the method in the report of the State Board of Health for 1891, I think of New York, and it was extensively employed by the engineer, Mr. Brown, and his assistants in 1891 and 1892 on the Hudson river, for determining the relative fecal pollution of the water. The results of other investigators have given general confirmatory evidence as to the value of this test as a criterion for the purity of water. It is the best method that we have at the present time, and probably will not be superceded because there is no indication at present that we are any nearer to a direct determination of the typhoid bacillus than we were perhaps ten years ago. If by the self purification of streams, you mean the sanitary purification of water for drinking purposes, it seems to me this method is applicable to that problem.

7295 Bacterial self-purification of streams consists in a reduction in the number of bacteria in a stream, which reduction is not due to an increase in the lower strata of the water, that is to say, not due simply to an imperfect or perfect sedimentation, but to a complete disappearance or destruction of the bacteria from the water, under examination.

Q. Do you know of any established principles of bacteriology and sanitary science that determine how far a stream can flow before purification is effected?

A. I do not know of any general principles that are involved, but I think each stream has certain special local conditions that need be looked into, which conditions depend on a variety of factors that vary from stream to stream, and what might be true for one stream might not necessarily be true for another. I think each stream under consideration must be investigated by itself. I do not recall any investigations of a similar problem extending over such a distance as that involved in this proceeding.

7296 I think the colon test is applicable to such a problem as that presented in the Illinois river. I believe that an instance where a stream becomes practically free from colon bacilli, in flowing through a country where no additional contamination from this organism occurs, is that of the Mississippi river below New Orleans. That has been worked out by Mr. Weston. I think there the colon bacillus disappears completely and no additional sewage enters. The failure to find the colon bacillus at New Orleans would lead me to think that all other bacteria that are closely related to the colon bacillus, such as the typhoid and dysentery bacilli and the various modifications, the para-colon and para-typhoid had also disappeared. The colon bacillus, as stated a few moments ago, is very closely related, biologically, to the typhoid bacillus—so closely, that up to within a certain number of years, the two were confused by many prominent bacteriologists * * * * * * *

7297 There are very few differences between the typhoid and the colon bacillus, and we are justified, I think, in inferring that whatever changes the colon undergoes are undergone in nature outside of the human body also by the typhoid. Whatever degenerative changes the colon undergoes are also undergone by the typhoid. But perhaps more rapidly under certain conditions because the typhoid is more parasitic. It has probably lost certain defensive properties, that is to say as a parasite it becomes more adapted to the human body and less adapted to life outside of the human body, and that the reduced power to live will also favor the increased destruction of the typhoid

bacillus in nature, a destruction which we generally assume is much more rapid than that of the more vigorous intestinal colon bacillus.

A typhoid bacillus will not multiply and increase in nature, that is, in ordinary water. It will grow rapidly in milk, but before the milk becomes very acid, but generally speaking, a typhoid bacillus does not increase and grow in conditions outside of the human body, excepting possibly in milk, under favorable conditions. I know of no other group of bacilli, but the colon, whose life in water is more likely to furnish an index as to the life of the typhoid bacillus. I am familiar with the figures and the data introduced by Prof. Jordan in this case, relative to the colon bacillus in the waters of the drainage canal and the upper Illinois river.

7298 I made a particularly careful examination of his tables as to the result of his examination of the Illinois river at its mouth, and of the Mississippi and Missouri rivers. From these tables, I should assume that the colon bacilli had very largely disappeared in their passage down the Illinois river and that the colon content of the Illinois river at Grafton is therefore less than that of the Missouri and the Mississippi rivers, or at least about the same. That is to say, the colon content of the Illinois at Grafton is not to any material degree superior to that of the tributaries of the Illinois river, and it is, on the whole less than the colon content of the Mississippi river and the Missouri river according to these tests. It would seem that the condition of the water at the mouth of the Illinois river was certainly not inferior, if not superior to that of the Mississippi river and the Missouri river, at these points, as I read the testimony in these tables. The Missouri river is, on the whole, more polluted than the Illinois river. According to these figures, there is not

7299 very much difference, but the benefit of the doubt rests with the Illinois river without any question. Basing myself upon the colon tests as I certainly should, in all such examinations, I should make the table speak for itself. So far as these colon determinations go, and so far as the inference drawn

from the colon contents is warranted, I should say that the Illinois river was superior in its sanitary quality to either of the other rivers, the Mississippi and Missouri.

It seems to me that in carefully studying the colon results obtained by Prof. Jordan, that some of the tributaries are slightly better than the Illinois river at Averyville and at Grafton and some are worse. According to these tables, there is an enormous destruction of colon bacilli down to Averyville in the Illinois river, and basing myself upon these, I should say that a similar, if not greater destruction of the typhoid bacilli had taken place down to that point.

7300 It seems to me that if virulent typhoid bacilli should actually pass from Chicago to the mouth of the Illinois river that it would be according to conditions and laws that we know nothing about, but that basing ourselves upon the close relationship of the colon to the typhoid bacillus and to this entire group of disease germs we are at present justified in saying that the virulent typhoid bacilli would be very largely destroyed at that point.

It would seem to me that the disappearance of the colon bacilli indicates that excluding a large amount of sewage which enters below Chicago the typhoid bacillus would probably be entirely eliminated during that long course from Chicago to the mouth of the Illinois river of three hundred and fifty odd miles.

I know of no bacteriological evidence that affords more suitable indications than the one in question, to-wit: the colon determinations.

7301 If a typhoid bacillus was found at St. Louis, it would be utterly impossible to identify the source of such typhoid bacillus. The presumption would be that the typhoid bacillus would come from the nearest sewage discharging town.

It seems to me that considering the enormous destruction of the colon bacillus from Chicago down to Averyville, the very great influx of sewage at Peoria, that the presumptive evidence is very strong that the typhoid bacillus from Chicago would not

the Chicago river alone had been turned into the Illinois river, instead of the present drainage canal with the 250,000 cubic feet of water per minute, I doubt if there would be very much difference at Henry as to the effect of the sewage of Chicago, or as to the dangerous qualities of the water.

7154 The Chicago sewage does not purify itself during its flow in the canal, which is 29 miles long. I should not think all of the sewage would be removed in a run of 39 miles. I don't know whether all of the pathogenic germs would be removed. I should think the pathogenic germs would be removed at a distance of 49 miles, if there were no new excess with water. I would not be willing to trust the water at 150 miles, because I should avoid it under all circumstances because of other contamination on the way.

I think the water would be safe at 150 miles but I would not recommend it at Grafton or New Orleans. Removing all sources of pollution other than Chicago from the Illinois river, in the absence of all contamination on the way, I think the water would be safe at Grafton. I would not recommend it, though. I would not recommend it at St. Louis, though I think it would be safe.

Q. Well, if you think it would be safe, why are you not willing to recommend it?

A. Because, we have ways of making it absolutely sure. My opinion on safety is an opinion. We have methods of being absolutely sure about our drinking water. Assuming that all sources of pollution are removed from the Illinois river, except the sewage from Chicago discharged into the canal with 250,000 cubic feet of water per minute, thence into the Illinois river, I think it would be safe to recommend the water of the

Illinois river at Grafton for domestic purposes but I would, of course, make tests in such a case.

7158 I think the use of the water is the best test in the long run.

7160 Assuming that it got no other contamination but the Chicago sewage, the water of the Illinois river would be safe at a place like Averyville.

7166 If I knew there were 10,000 cases of typhoid fever in Chicago and that the discharges of those patients were passed into the canal, I would not recommend the water at Grafton, under any circumstances. If I knew there were 100 cases of typhoid fever during the months of May, June, July August and September, in Chicago, I would boil the water at Grafton until we had more knowledge. I think it would be safe, but I would boil it, or filter it.

7167 My reason for this is that I always use the most perfect method, whenever I can, in technic. I should think that typhoid germs would, or might live as long as ten days in running water. I do not think they would live longer than thirty days. I think they would live longer in a sample of water kept in a laboratory than they would in the same water in a running stream.

7169 Q. I thought you stated a moment ago that you were of opinion that they would live longer in the laboratory sample?

A. Well, it is not a strong opinion. I have that idea about it. It is not a strong opinion.

Q. Then you do not care to express an opinion on it?

A. I would rather not. I do not think they would live more than thirty days in the Illinois river. I do not think they would live that long if they started in the upper part of the river.

7170 They would disappear more rapidly from the canal in the summer time than in the winter time. I think it very improbable that under the worst possible circumstances

the sewage of Chicago will affect the water in the Mississippi river at Grafton. In my opinion, it would not and cannot affect the sanitary condition of the water in the Mississippi river at Grafton.

7171 I think the typhoid bacilli would die less quickly when the saprophytic bacteria—one of the important factors —are slow in growing.

7186 I am undertaking to give what Prof. Long believes, in reference particularly to the Averyville situation, chemically speaking. I know nothing of the conditions at that point, other than what I have learned from others with regard to the chemistry.

7198 (Witness states information he has secured upon which he bases the opinions given in his direct examination.) This is a resume of the facts ascertained in the investigation made by the defendant.

7206 I am not sure that the addition of 250,000 cubic feet of water per minute into the drainage canal, would make no very great difference either way, as to the life of pathogenic bacteria. I think the tendency would be to increase the life of certain bacteria.

7208 I would say that in my opinion, the water in the Illinois river at Averyville was not materially affected by the sewage of Chicago, but would not recommend any water for drinking purposes without tests.

7209 If I knew that it did not take the water five days to come from Chicago to Averyville, it would have an affect upon my opinion. I should not be sure that in five days absolutely every typhoid bacillus would be dead. I should say that in my opinion there is no evidence that the Illinois river water at Grafton is affected by the sewage of Chicago, but I would advise the people of Grafton not to use it without filtration or boiling. I would give it, as my opinion, that the water at Grafton is in no wise affected at any time of the year by the

sewage of Chicago. That would be my opinion. I would not put myself in the position of recommending my opinion.

7211 I would not recommend the water under any circumstances.

7212 All information that I can gather, or could gather would have an effect upon the formation of my opinion, and upon the information that I received, I would be willing to state it as my opinion that the water at Grafton is probably safe, as far as the city of Chicago is concerned—as far as the sewage of the city of Chicago is concerned, but I would not recommend its use because I do not recemmend any river water for use.

7213 If the water comes from Chicago to St. Louis in ten days and the sewage turned into the canal was typhoid infected, considering all the conditions of the river, I would state it as my opinion that as far as the typhoid bacilli coming from Cnicago are concerned, Grafton and St. Louis would not be menaced. Under no conditions that will ever be realized, in my opinion, will typhoid germs come from Chicago to St. Louis in ten days, with the water. I think if you had a sterilized tube of distilled water leading from Chicago to St. Louis, coming down there in ten days, you could carry live typhoid bacilli from one city to the other.

7215 The biological test is the best one, as to whether typhoid germs are in water. In my opinion, the water at Averyville would be reasonably safe and the biological test could not be applied there because of the contamination between Chicago and Averyville.

7216 At Lawrence, the germs in the reservoirs holding 14 days water supply, were in reservoirs containing water such as is used for drinking purposes, whereas the typhoid bacilli coming from Chicago toward Averyville, are subject to the tremendous influence of the sewage in the canal.

7217 I should think a great many of the typhoid germs that came from the sewers of Chicago are dead before they go over the Bear Trap dam. A very great many more would

be dead by the time they got to La Salle and I think they would probably all be dead by the time they got to Averyville.

7220 I would say that in my opinion, in all probability, the water would be reasonably safe at Averyville, as safe as most water supplies in this country.

7240 It is my opinion that some of the processes of septic operation go on in the drainage canal, even in the presence of oxygen.

7244 In looking for the source of typhoid infection in St. Louis, I should look for it within 25 or 30 miles.

7248 In my opinion, typhoid bacilli would not pass from Chicago to St. Louis alive, partly because of sedimentation.

7249 I should think it very improbable that any place farther away than 75 miles, was responsible for typhoid fever existing in St. Louis.

7250 I do not believe that typhoid fever can come a distance of 175 miles.

7263 The letters which I have had from Dr. Roland Hill of St. Louis, have not said anything about there being but little malarial fever in the Mississippi valley for the last three years. The tables which I have read in evidence, do not indicate to me that there has been a falling off in malarial fever. I do not mean to impeach the integrity of the physicians of St. Louis, but I do mean to intimate that there have been improper diagnoses made by the physicians of that city.

7265 According to the statistics in evidence, there is an increase in the figures under the head of typhoid alone, but not under the head of the two groups which would include the remittent, etc. In 1902, there was a distinct increase in typhoid alone and in the combined groups. The increase is not so great but what it might be—it might occur in any year. For instance, if you examine the statistics farther back, you find in the years 1890, 1891, 1892, 1893 and 1894, more cases in the combined group. Attributing the typhoid in all instances to the pollution of the water supply, it simply means that the con-

ditions in the water are not the same from year to year, although the source of the water supply is the same. Assuming that all the deaths are due to water pollution, it would indicate either that there were differences from year to year, in the pollution of the water supply, or that for some reason or another, the people were more susceptible one year than another.

7267 I should say that if typhoid were occurring in Alton and St. Charles, and the sewage was being poured into the river, and those two towns are within 75 miles of St. Louis, I should think a slight difference in the number of cases in two or three years in St. Louis, might easily occur without any change in the amount of typhoid being put into the river. I would not at all suppose that the towns must necessarily have 5,000 inhabitants in order to pollute the water. I think a single case of typhoid, occurring near the intake of a village of twenty houses would be much more significant than the sewage from a town of 5,000 a great deal farther away, if the excreta from the typhoid patient got into the river in any way.

Q. But that, doctor, would come in the shape of epidemics, would it not, being so close to the city that it would not be continuous?

A. I regard typhoid fever as being epidemic in St. Louis all the time; not a great epidemic, but still, epidemic.

7268 I should think if the settling basins in St. Louis were properly conducted that they would diminish the typhoid bacilli.

7269 I cannot give you the exact length of time that anthrax spores will live in water or earth, but I know they will live a very long time—that they are most resistant. I think they will live at least years, when they are kept dry. If they were wet, I should think they would grow out into bacilli. Unless they had the proper temperature and media, they would not grow out into bacilli. Tetanus spores will also live a considerable length of time. They are present in garden earth all the time.

A. I say I would extend it to get the purest water, to the middle of the lake, which of course is not practicable.

7123 Q. But if I understand you correctly doctor, you take the position that it would be necessary in your judgment, to extend the mains so far as you could trace the chemical impurities because of the likelihood of the bacteria being present?

A. No, I do not intend to leave that impression at all, because chemical impurities will go wherever the water goes, being in solution; they can go ultimately a thousand miles.

Q. Do you know that the bacteria won't go a thousand miles?

A. All the evidence is against it.

7124 When I speak of the longevity of typhoid germs, and apply their longevity to the water of the Illinois river, I am very glad to acknowledge that I borrow the experience of other men and do not speak from actual personal experience of my own.

7129 In expressing an opinion on the longevity of typhoid bacilli, I do so solely on what people have told me with reference to it. I am very glad to do that because I do not think I could give you a more reliable source. Among others, Dr. Jordan has told me how long typhoid germs would live in river water. I have talked with him, off and on during the last three years and also with Dr. Kekoten.

7135 The addition of 250,000 cubic feet of water per minute in the canal would have a tendency to prolong the life of the typhoid germ. I was about to say that this refers to the life of the bacillus as I understand it, the dilution is not great enough to interfere with the killing off of typhoid bacilli by the saprophytic bacteria. The greater the sewage pollution, the less the limit of the typhoid germs, other things being equal.

7138 I think that it would probably be true that the typhoid germs, for instance, would disappear much more rapidly if the sewage of Chicago was turned into the drainage canal

unmixed with the water of Lake Michigan, than it will now as it is being mixed with the water from Lake Michigan.

7141 I think the addition of 250,000 cubic feet of water per minute would also prolong the longevity of the typhoid germs that are discharged into the Illinois river from all the points below Chicago, but in a progressively diminished manner, because the relative percentage of increase would grow progressively less, owing to the contents of the tributaries coming in below. It might have been better for the upper part of the river to have turned the water and sewage of Chicago from the Chicago river, as it originally existed, into the Illinois river, without any lake water, than to have turned the lake water and sewage, at the rate of 250,000 cubic feet per minute, through the canal into the river, but I doubt if it makes any appreciable difference with the lower part of the river.

7143 For two reasons, that I think the stream would purify itself so thoroughly at the lower end of the river, that the pollution would be inappreciable; and the other reason that the increase in volume of water relatively, would be so slight in the lower part of the river, owing to the access of so many tributaries in between, that any increase in the longevity of pathogenic bacteria would be doubtful, immeasurable.

Assuming that the volume of water flowing down the Illinois river at Grafton during certain seasons of the year since the opening of the canal is less than the total amount of water passing through the canal, I should think that Grafton was so far below Chicago that it was a matter that had very little bearing upon the question because of the self-purification of the stream.

7144 My opinion is that typhoid germs die out quicker when there is a great deal of sewage, than when there is not. I am not sure that any typhoid germs get as far from Chicago as Grafton. My opinion is that they do not.

7153 I would not recommend the water in the Illinois river nor the Mississippi or Missouri, for domestic purposes. If

of water in there. The water was very high all over the country at that time. 1892 was an exceptional flood year.

7335 RE-DIRECT EXAMINATION, by Mr. Todd:

The levee of the Pekin Levee Co. was washed out in 1892. The several levee districts to which I have referred, do not withstand the flood of the Illinois river. The one opposite Beardstown is the best one I know of along the river and I believe it has broken once. From my knowledge of the Illinois river I do not know of any concerted movement to levy that river from its mouth to La Salle.

7336 LEONARD P. KINNICUTT, examined in chief by Mr. Todd:

Am director of the Chemical Department of the Worcester Polytechnic Institute, located in Worcester, Mass.

7337 (Gives educational qualifications.) Have made a special study of sanitary problems, beginning in the year 1882, which study I have continued from that time. I have made a special study of the analysis of water, both chemical and bacterial, and I am continually employed in making such determinations.

7338 I am acquainted with the physical conditions of the Chicago river, the drainage canal, the Des Plaines and the Illinois rivers, and the Mississippi river. In September of last year I passed through the drainage canal on a tug boat, which went as far down as Joliet, noticing the Des Plaines river. Took the train to Peru, then took the boat at Peru and journeyed down the river as far as St. Louis.

7339 Have made a special study of the problem of sewage disposal both in the United States and in England.

7340 (Witness describes a septic tank and the processes which take place in same.)

7341 Septic operation will take place, I believe, fully as well in an open tank as in a closed tank. As an illustration, I might state that at Birmingham, England, which has the largest installation of septic tanks—over 20 in number—all are

uncovered. (Witness describes operations taking place in a septic tank built by him for experimental purposes.)

7342 As I passed along the sanitary canal in a tug boat from Chicago to Lockport, I took particular notice of the indications of the sanitary canal acting as a septic tank. Among the chief indications that it was so acting was that gas was being given off and I noticed bubbles of gas given off from the liquid as far as Lemont. After passing Lemont I noticed no further development taking place. The odor from parts of the sanitary canal, especially near Chicago, remind you of the odor from the septic tank. Further down there was the odor that you obtain where the effluent of a sedimentation tank passes over or is allowed to fall over rocks or passes over a dam.

I have prepared tables showing septic operations taking place in the sanitary canal. They are tables A, B, C, D and E and reproduced on pages 7344, 7345, 7346 and 7347. Table E being a table showing the action of a septic tank on the removal of substances contained in sewage, and reproduced on page 7348.

7349 If analyses are made of the crude sewage, and of the effluent from the septic tank we find that as a rule the amount of free ammonia in the effluent is greater than in the sewage; that the amount of total or soluble albuminoid ammonia and of suspended albuminoid ammonia is less in the effluent than it is in the crude sewage; that the amount of nitrogen as nitrates and nitrites is very small in the effluent and as well as in crude sewage, but there is a reduction of nitrogen as nitrites and nitrates.

From the analysis that I have made showing the character of the water at Lockport and the character of the water in the canal at Kedzie avenue, these results indicate very strongly that the septic action has taken place during the passage of water containing sewage through this canal, as shown by the increase in free ammonia, the decrease in albuminoid ammonia, soluble albuminoid ammonia, also in the decrease in oxygen consumed, soluble and suspended; that the results agree in their general characteristics with results that have been obtained by the exam-

ination of crude sewage and the effluent from the septic tank in the various places that I have given in table E. The changes are exactly the same in character, the difference only being in amount.

This septic action has a purifying effect upon the sewage of Chicago as it passes through the drainage canal. It also renders the substances which still remain in the sewage more easily acted upon when the sewage enters the river, and it purifies the sewage by removing a part of the solid matter that was in the sewage, by throwing it down to the bottom of the canal and by the removal of part of the solid matter by changing it into gas.

7350 (Witness quotes from the report of Prof. Boyce, wherein he states that "experiments made in Manchester show that B. coli diminishes during the stay in the septic tank, and experiments conducted in the laboratory show that the septic tank liquid is inimical to B. coli and therefore to other more delicate bacteria." (Witness quotes from other authorities and then states:) I will say that my own opinion is that it diminishes the number of B. coli, and the more delicate pathogenic germs and that the total number of bacteria is diminished by ten or fifteen per cent.

7351 (Witness states what conclusions he draws from the presence of the different chemical elements when found by his determinations in water.) (This answer is an explanation of what the various chemical constituents, as found by chemical analyses, determine as to the past history and present condition of the water under investigation.)

7354 I have studied the chemical data prepared by Prof. Long and the chemical and bacterial data prepared by Prof. Jordan, Palmer, Burrill and Zeit heretofore introduced in evidence, also the tables introduced in evidence by these witnesses.

I have taken the analytical data as given by Professor Long in the Illinois State Board of Health, 1901, which are the results of his examinations of the water at the various stations

from Chicago to Grafton on the Illinois river, both for 1899 and 1900.

(Witness compares tables No. 1 to 4, inclusive.)

7355 Table 5, Joliet, Illinois and Michigan canal: The distance of Joliet from Lockport is only four miles, and the results show that but little change has taken place in the sewage in its flow from Lockport to Joliet. The chief difference in results at this point from those obtained at Lockport, being due, in my opinion, to dilution by water of the Des Plaines river which at this point is mixed with the waters from the canal.

Table 7, Morris, Illinois river: The Kankakee river enters the Des Plaines river about nine miles above Morris and its diluting effect is shown by the reduction of chlorine from 85.49 to 61.8. The water of the Kankakee river is a much purer water than that of the Des Plaines river at the point of junction, and so the water of the Des Plaines is purified to a certain degree by dilution. That the organic matter in the water has begun to undergo decomposition, is shown by the decrease in free

7356 and albuminoid ammonia and increase in nitrogen as nitrites and nitrates. There has also been a decided deposition of suspended matter, a large part of which was oxygen consuming substances, as the suspended oxygen consumed at Joliet is 10.59, while at Morris it is only 1.09.

Table 8, Ottawa, Illinois river: There has been a very decided change in the purity of the water in the river between Morris and Ottawa, a distance of about 24 miles. The chlorine shows that there has been very little dilution of the water of the river between these points, and the very decided decrease in free and albuminoid ammonia with increase if nitrogen as nitrites and nitrates shows that bacterial decomposition of the organic matter is rapidly taking place, changing the organic matter into mineral matter. There has also been a certain amount of deposition of suspended matter. Between Morris and Ottawa there is a dam, the Marseilles dam, I believe, but this would have little effect in the character of the water beyond bringing about

the removal of suspended matter, there being, according to Prof. Palmer's results, dissolved oxygen in the water.

Table 10, La Salle, Illinois river: These samples were taken about 600 feet above the mouth of the Big Vermilion, and although there has been some dilution as shown by the reduction in chlorine, the very decided decrease in free and albuminoid ammonia with corresponding increase in nitrogen as nitrates and the decided decrease in oxygen consumed shows that during the stretch of river between Ottawa and La Salle the processes of purification have been very active.

7357 Table 12, Henry: The slight increase in chlorine would indicate a slight addition of sewage to the river, probably from La Salle and Peru, total population 20,000. There has, however, been only slight changes between.

Table 13, Peoria Narrows: The chlorine shows that there has been more or less dilution between Henry and the Narrows, but the great change has been in the removal of free ammonia and nitrogen as nitrites. This shows that the principal change between Henry and the Narrows has been the last process in the changing of the organic matters of sewage into mineral matter.

Table 14, Wesley City: The increase in all the above constituents, especially the free ammonia, albuminoid ammonia and oxygen consumed, shows that a large amount of organic matter has been added to the river between Peoria Narrows and Wesley City, a distance of only about six miles. This addition from my knowledge of the river, is from the town of Peoria, 50,000 inhabitants, with its large cattle sheds and distilleries.

Table 15, Pekin: The distance to Pekin from Wesley City is about ten miles, yet in this stretch, a great amount of purification seems to have taken place, much more than I should have expected. This is shown by the very great decrease in free and albuminoid ammonia, oxygen consumed, and increase in nitrites and nitrates. There is no marked dilution as shown by the amount of chlorine.

7358 Table 16, Havana: We see here, as at Peoria Narrows, the final changes of organic matter into mineral matter taking place.

Table 26, Grafton: The distance from Havana to Grafton is 119 miles. There is a dam between Grafton and Havana and the water of the river is diluted by the Spoon and Sangamon rivers, both of which enter the Illinois between Havana and Grafton. The water at Grafton, as shown by the analyses, has been so purified between Havana and Grafton that it now closely resembles the water at Peoria Narrows. It shows only in the chlorine and nitrogen as nitrates evidence of part pollution.

Table 21, Grafton on the Mississippi: The river differs greatly from the Illinois in the amount of chlorine it contains, 177 against 17.5, and while it contains a less amount of solid substances in solution than the Illinois, it contains a greater amount of suspended matter. The amount of organic nitrogenous matter and carbonaceous matter in the two rivers is about the same, as shown by the albuminoid ammonia and oxygen consumed.

I have also prepared tables from the results of Professor Long's analyses at the various stations from Chicago to Grafton, from June to October, 1900.

7359 Table 41, Chicago city water: These analyses would indicate that the water was not quite as pure in 1899 as 1900, but are results that would be obtained with a potable water.

Table 43, Western avenue bridge, drainage canal: If this is compared with the analyses of the water in the Illinois and Michigan canal in 1899 at Bridgeport, it is seen that it is a very much more dilute sewage, or sewage mixed with a much larger amount of water.

Table 44, Lockport canal: This analysis when taken in connection with table 43, as I have already pointed out, shows that the dilute sewage has undergone very decided changes in its passage through the canal.

source of infection I should first look to the points nearer, by all means, and if these could be eliminated, then I think I should look to the city of Chicago.

7304 I think it would be highly important to locate the nearest sources first because of the vulnerability of the typhoid bacillus in water. The further the area of infection the less the danger of the typhoid bacilli reaching the water supply. A few bacilli discharged into a stream near by would be much more dangerous than a large number discharged at a much greater distance.

7305 The results of Professors Jordan, Zeit and Russell have introduced a new factor into the problem in that they have defined for us, perhaps for the first time, the viability of the typhoid bacillus in polluted water. Before that time of course the results were not very definite unless we took into account the viability of the colon bacillus, but now it seems that the typhoid bacillus is fairly rapidly destroyed in polluted water, more rapidly than we have believed, and that rapidity of destruction would indicate what I suggested a moment ago, that possibly the typhoid bacillus is stimulated enough to multiply in sewage polluted water to be promptly destroyed whereas in water which contains very little organic matter its life is preserved a longer time because of a condition of latency and absence of that stimulation to multiply which I assume is very destructive to bacteria in general. If these experiments are carrect, and I feel quite prepared to take the risk of accepting all of those experiments of Professors Jordan and the other gentlemen—if they are correct—then I think it would be physically impossible for the typhoid bacillus to reach St. Louis, starting at Chicago.

7306 I know of only two cases in Massachusetts of death resulting from malaria.

Q. Are remittent, intermittent, typho-malaria, congestive and simple continued fevers distinct types of disease and so recognized by bacteriologists and clinicians?

A. It is very rare that typhoid fever and malarial fever co-exist and these cases are so rare as generally to go on record in medical publications. These terms and especially the term remittent fever figured quite extensively in medical publications about twenty years ago, but since that time it has almost wholly disappeared because of the more accurate means of diagnosis.

Classifying deaths from typhoid in one column and those from remittent, etc. fevers in another column, is, at least, a very indefinite form of classification, because we would assume that under the terms, remittent and simple continued and typho-malarial, we would have either one or the other disease, either typhoid or malaria or a mixture of the two, which rarely occurs. Where such classification occurs, showing almost an equal number of cases under the remittent, etc. group, with those in the typhoid group, I do not think such a classification would furnish a correct idea of the prevalence of typhoid fever in a given community. The classification as you have mentioned it, would indicate that the best means of diagnosis were not resorted to in determining the nature of those diseases.

7308 CROSS-EXAMINATION, by Mr. Corum:

In the Hudson river, the experiment made at Albany determined that that river purified itself to the extent that the number of bacteria dropped from an average of 10,000 per c.c. to about 300 per cubic centimeter within this distance of about 18 miles, I think. I do not remember the exact number of miles. The fermentation test is not rendered inaccurate by the more rapid multiplication in the tube of other saprophytic forms. (Witness gives reasons.)

7310 I understand that colon bacillus was not found at New Orleans, even with the use of a large amount of water, although I am prepared to be corrected on that point, by printed evidence.

7311 It follows logically that if typhoid germs were discharged into the river at Peoria, the increase in the volume of the water by the canal would carry the typhoid to St. Louis in a

shorter space of time. It also follows that there would be a great deal more dilution of the Peoria sewage.

7312 The evidence upon which I am basing my statement, and I think it is perfectly reliable, shows that the colon bacilli largely disappear at Averyville or before they reach this second source of contamination—the group of towns at Peoria—consequently it would be inferred that the colon bacilli which are at St. Louis are largely recruited from the places further down and that the colon bacilli which have almost disappeared at Averyville would have completely disappeared at the mouth of the Illinois river.

7313 VICTOR C. VAUGHN, examined in chief by Mr. Todd: I am a physician and teacher. Reside at Ann Arbor, Michigan, and am connected with the University of Michigan. Have been teaching at that University since 1876, but studied with Prof. Koch, in the University of Berlin, two or three times. I teach hygiene and physiological chemistry. Am a member of the State Board of Health of Michigan. Have been called upon frequently to examine into epidemics in the state and am still serving on the United States Government Commission for the study of typhoid fever. Enlisted in the army in 1898 and was appointed on this commission in August of that year. After my return from Santiago, in connection with Major Walter Reed, and Major Shakespearre, I went to Camps Alger, Fernandino, Jacksonville, Huntsville, Alabama, Chickamagua, Georgia; Knoxville, Tenn.; Camp Meade, Pennsylvania, and the other members of the commission went to Montauk. I did not. I was sick at the time. I think I must have seen four or five thousand cases of typhoid fever. As a member of the commission, I have been engaged practically ever since that time in writing up the statistics and studying the spread of typhoid fever and I have also been called upon frequently to investigate outbreaks of typhoid fever in different parts of the country, in Michigan and other states as well.

7315 I have made a special study of typhoid and malarial fever from the standpoint of a bacteriologist and clinician. Our

commission had charge of all the diagnoses that were made in the army camps after the appointment of the commission, that is, we selected the men and put them to work and overlooked their work in the various camps in the United States. Typhoid fever is an acute septicaemia, due to infection with a specific germ known as bacillus typhosus. Malarial fever is a disease due to infection with a malarial parasite, of which there are at least three well known varieties. Most of the cases diagnosed under the different heads of intermittent, remittent, typho-malarial, congestive and simple continued fever, are forms of typhoid fever. Malaria is sometimes called remittent fever, but the majority of the cases in this country that are diagnosed under those heads, especially in the northern parts of the United States, are really cases of typhoid fever.

7316 Remittent, etc. fevers are not distinct types of disease. They almost invariably mean typhoid fever. (The number of deaths from typhoid in St. Louis from 1890 to 1903 and the number of deaths from remittent, etc. fevers during the same period, read to witness.)

7317 The number of deaths reported as occurring from typhoid fever alone, in St. Louis, do not properly represent, in my opinion, the total number of typhoid deaths actually occurring in the city for the period in question. (Witness gives reasons for his answer.)

7319 I am sure there is no city in the United States where there are so many deaths from malaria as are reported from St. Louis. 100 per cent of the deaths reported in the column "Remittent, etc. fevers," should be classed as typhoid and none as malarial fever. There are practically no deaths from malaria in this country unless it is in New Orleans, or some other extreme southern city.

7320 It is generally recognized by bacteriologists and clinicians, that classifying typhoid fever in one column and intermittent, remtitent, typho-malarial, congestive and simple continued fevers in another column, in board of health reports of cities, is an improper classification from a scientific stand-

point as affording a true indication of the mortality from typhoid fever and malaria. (Table is read to witness, showing typhoid mortality by months under column "A" and mortality from remittent, etc. fevers under column "B" for the years 1895 to 1903 inclusive. Witness states:) I think the total deaths there as reported from all of these cases more accurately
7321 give the number of deaths from typhoid fever. Without knowing anything about the local conditions in St. Louis, simply as a student of epidemiology, and looking at the distribution of these diseases according to months, I should say that the probabilities are that typhoid fever in St. Louis, with the possible exception of the year 1892, was due to local causes, rather than to any infection of the general water supply.

7322 As I stated a moment ago these figures as given here showing the distribution of typhoid fever render it highly probable that the local conditions, such as infected or polluted wells indicated the distribution of typhoid fever by contact were the causes of the spread of typhoid fever in St. Louis rather than the infection of the general water supply. I should answer your question then specifically by saying polluted wells, if they were specifically polluted with typhoid fever, the use of the water from such wells, would undoubterly cause typhoid fever.

The circular letters issued in 1900 and 1901 by the St. Louis Board of Health evidently shows in the statistics heretofore read in evidence, by an increase in the number of deaths reported from typhoid fever. The two tables—one showing death rate from typhoid fever and the other from remittent, etc. fevers, taken separately do not correctly show the death rate from typhoid fever.

7325 My opinion is based upon the fact which is well known to most physicians and certainly I have special reasons for knowing it, that malaria is not a frequent disease in this country and is certainly a very rare cause of death. In order to arrive at the typhoid fever mortality in St. Louis, the two tables should be combined. The death rate in Buffalo has increased quite markedly, also in New York.

7326 Typhoid fever has been more widely disseminated over the country and there have been more cases and more deaths during the last five years. Other cities besides St. Louis show an increase. Taking the table introduced by Prof. Jordan, as compiled from the typhoid fever and remittent, etc. fever mortality of St. Louis by Farr's Formula, this table shows an increase in typhoid, but not such as would be characterized as an epidemic.

7327 An epidemic of typhoid fever, and especially a water epidemic of typhoid fever, is where the increase in typhoid fever amounts up to 100 per cent or more, and even 200, 300 or 400 per cent.

7328 The increase as there shown is, on the whole, a gradual increase such as you might expect would be due to local conditions, especially if wells were getting more and more filthy and were not condemned. The charts introduced in evidence do not show that there is any relation between typhoid fever in Chicago and typhoid fever in St. Louis.

7329 I think that there is no evidence so far as I can see from these figures that the drainage canal has had anything to do with the typhoid fever in St. Louis for the following reasons:

In the first place, as I have already stated, the distribution of typhoid fever in St. Louis as shown in these tables, is indicative of local contamination and spreading by contact rather than of any general water infection.

In the second place there are certain cities in the list that I have given here where the increase in typhoid fever has been more marked than in St. Louis, and in these cases notably that of Buffalo, the drainage of Chicago has been turned away from Buffalo rather than to it.

I think that there has been a gradual increase of typhoid fever throughout the country for the last few years, and the increase in St. Louis has been gradual. It has been slow and I do not think that there is any evidence from the figures that there has been any great contamination of the water supply of St.

Louis. There has been no explosive outbreak of typhoid fever there.

7330 Typhoid fever is sometimes spread by other means than that of drinking water, as is shown by the number of deaths that occurred, during the Spanish-American war, at Jacksonville, Florida.

7331 CROSS-EXAMINATION, by Mr. Corum:

The fact remains that typhoid fever may be scattered or contracted by the use of polluted drinking water.

7332 EBEN J. WARD, examined in chief by Mr. Todd:

Am civil engineer and have been since 1880. In 1890 and 1892 I made a cognizance of the Illinois river for the purpose of ascertaining the number of of acres that were inundated on the bottoms of that river. The flood of 1890 was what we would call an upper river flood. By that, I mean that as far as Peoria, the low lands were considerably inundated, but from Peoria down, the water was confined almost entirely to the channel proper of the river and slight rises along the bayous and inlets.

7333 That was in 1890. In 1892, there was a general overflow throughout the entire Illinois river, that is the river below Peoria, it overflowed practically from bluff to bluff. In 1890, below Peoria, the water was confined to the channel proper of the river, but in 1892 it overflowed from bluff to bluff, clear to the mouth of the river. The number of acres subject to overflow, from the eastern line of Grundy county to the La Grange dam is 200,000 acres, this being my estimate for 1892. Below there, I should estimate there would be 200,000 acres more, although I did not trace the water line on the map below the La Grange dam for 1892. I would estimate the land subject to overflow along the Illinois valley from Joliet to the mouth of the river, to be in the neighborhood of about 400,000 acres.

CROSS-EXAMINATION, by Mr. Corum:

There is one levee district now opposite Pekin, about one and a half miles long. There is one opposite Beardstown which is two or two and a half miles long, also one opposite Havana which is a couple of miles long. In 1892 there was a vast volume

reach St. Louis because it is highly probable that the colon bacilli at the mouth of the Illinois river are probably those that have been introduced further down the stream, say at Peoria and other sewage-discharging places.

7302 I have no precise data on the subject as to whether typhoid germs will live as long in pure water as in sewage polluted water. Sewage polluted waters may, under certain conditions, be more destructive than pure water within certain times and within certain limits.

It would seem that some of the epidemics that have occurred in the past have been due to relatively pure water which accidentally carried the typhoid bacillus a short distance or a relatively short distance, such as the epidemics at Ithaca, New York, and at Plymouth, Pennsylvania.

7303 If it were true that a relation obtained between typhoid fever in Chicago and typhoid fever in St. Louis, I should think that the two curves of typhoid would be very much alike and the St. Louis curve would be slightly retarded in time. (Wtiness is asked to examine two charts showing typhoid deaths in Chicago and St. Louis, with the St. Louis deaths platted one month in advance, as introduced by Prof. Mason, and states:) I am unable to see any direct connection between the typhoid curve of Chicago and that of St. Louis from these diagrams. The upward curve in the St. Louis charts is one which seems to correspond with the usual summer and fall increase in typhoid, which is manifested throughout the civilized world, but I fail to see any direct relation between the two. I think it is generally conceded that typhoid fever in our hospitals, grows in August, September and October each year. That is the time when cases are looked for. I have examined the typhoid statistics introduced in evidence in this case showing typhoid conditions in St. Louis and Chicago, and from the colon determinations of the Mississippi river at the Chain of Rocks. I should hardly consider the river water a satisfactory water for public use without previous preparation or previous filtration. Assuming that the typhoid condition of St. Louis was due to water supply, for the

Table 45, Joliet, Des Plaines river: This analysis shows that the water is not as pure as it has been up there, but when compared with the analyses made in 1899, shows that it contains very much less organic matter than it did at that time.

Table 46, Morris: The dilution by the waters of the Kankakee is here shown by the chlorine as in 1899. The water is very much purer than in 1899.

Table 47, Ottawa: There has been even more marked purification of the water in its run of 24 miles in 1900 than 1899, as shown by the reduction of free albuminoid ammonia, and oxygen consumed, and by increase of nitrites and nitrates. That there has been little, if any dilution, is shown by the chlorine.

The water is much purer than in 1899.

7360 Table 49, La Salle: The purification which was noted at Ottawa has continued. The chlorine shows the effect of slight dilution. River much purer than in 1899.

Table 51, Henry: The results similar to those obtained in 1899, the slight increase in chlorine, indicates the addition of the sewage of La Salle and Peru. Slight changes as regards organic matter. River purer than in 1899.

Table 52, Peoria Narrows: The change as was the case in 1899, is the decrease in free ammonia, albuminoid ammonia and nitrogen as nitrites. Water much purer than in 1899.

Table 53, Wesley City: The analyses show the addition of the sewage of Peoria.

Table 54, Pekin: As in 1899, a great amount of purification seems to have taken place between Wesley City and Pekin, a distance of 9 miles. River much purer than in 1899.

7361 Table 55, Havana: We have here in the 24 miles similar results to 1899, a very slight increase in free ammonia and in nitrates, and a slight decrease in albuminoid ammonia. Mackinaw creek enters the river above Havana.

Table 58, Grafton: The water between Havana and Grafton has been so purified that the nitrates and chlorine are the only indications of the pollution of the river at Peoria.

Table 59, Grafton on Mississippi river: The great difference in the Mississippi at Grafton from the Illinois at Grafton in 1900, as in 1899, was in the amount of chlorine, 2 against 10.6, and in the suspended matter. The Mississippi, as is shown by the albuminoid ammonia, and oxygen consumed contained in 1900 more organic matter than the Illinois in 1900 and figures for oxygen consumed show a greater amount of organic matter both in solution and suspension.

I have prepared a table from the chemical and bacterial analysis of Professors Jordan, Palmer, Burrill and Zeit, as they appear in Streams Examinations, which have been introduced in evidence in this case, and the tables of Professor Long as they appear in the Board of Health report of the State of Illinois, which also have been introduced in evidence in this case.

7362 The general method employed in making this table was to obtain the mean of the average of the analyses made by these various named persons during given periods of examination, as given in Streams Examinations, and the report of the State Board of Health of Illinois for 1901, which tables have already been introduced in evidence, and during times which were comparable with each other. In the examination of these tables I struck an average for similar periods in different years of the analyses, which tables have already been introduced in evidence and where that method was not pursued, my tables show it. These tables will be subsequently introduced in evidence. I have prepared tables 41 to 52 inclusive, which are the mean of Jordan's and Palmer's results, May to December, inclusive, 1899. These tables are reproduced on pages 7363 to 7368 inclusive.

7369 These tables were prepared by taking the average of the results of Professor Palmer and Professor Jordan, as given in Streams Examination, at the different places mentioned in each table. I have prepared a chart based upon the averages, of the chemical results in the tables of Professors Jordan and Palmer, which I have just introduced in evidence. The chart, with the caption "Mean results Illinois river, Chemical

table, Jordan and Palmer, months of May to December, inclusive, of 1899, L. P. Kinnicutt," is reproduced on p. 7370.

7371 At Joliet the high free ammonia, the high albuminoid ammonia the high oxygen consumed, the low nitrites and low nitrates show that at this point we have a water very badly polluted by organic matter or sewage. The rapid decrease in the amount of ammonia, free ammonia and albuminoid ammonia, and the oxygen consumed, from Joliet to Morris, and at the same time the increase in nitrogen as nitrites and nitrates shows the amount of purification that has taken place between these places. The most active zone of decomposition seems to be in the neighborhood of Ottawa. This is shown not only by the falling curves denoting free albuminoid ammonia and oxygen consumed but by the rising curves denoting nitrogen as nitrites and nitrates, the nitrite curve reaching its maximum at this point. As we proceed down the river from Ottawa to La Salle the curve shews continued purification. The slight fall in the curve from nitrogen as nitrates being due to the removal of nitrates from the water by green plant life. From La Salle to Henry the curve for the free ammonia and nitrogen as nitrites still descend. The slight rise in the curve for albuminoid ammonia and oxygen consumed indicates a slight addition of organic matter to the water of the river between La Salle and Henry. Below La Salle the purification continues down

7372 to Averyville as shown by the gradual decrease of free and albuminoid ammonia, nitrogen consumed and nitrogen as nitrites.

At Averyville the chart shows, as was shown by Professor Long's table, the result of the final change of the organic to inorganic matter; low free ammonia; low free albuminoid ammonia; low nitrogen consumed with high nitrates. The results obtained by Long at Averyville from July 5th to November 25th, agree closely with the mean of Jordan's and Palmer's results from May to December, as is shown in the following table. (See table on page 7372.)

From Averyville to Wesley City we notice the effect of the

contamination at Peoria by the rise in free ammonia, albuminoid ammonia, oxygen consumed and the decrease in nitrites and nitrates.

Jordan's and Palmer's results show less effect from this contamination than do Professor Long's analysis. This may be due to the possibility that at the point where Professor Long collected his samples, there may not have been complet. mixing of the sewage of Peoria with the river water, or that where Palmer and Jordan's samples were taken there was not a complete mixing of the river water with the sewage.

Between Wesley City and Pekin the purification again begins and this purification is continued all the way down to Grafton where the low albuminoid ammonia, low nitrogen as nitrites, low oxygen consumed, shows the removal of the polluted matter entering the river at Peoria. If we again com-

7373 pare the results of Professor Long with the mean of Professor Jordan and Palmer we find a close agreement as regards the condition of the water at Grafton.

(See page 7373 for comparison referred to.) I have prepared tables based upon chemical analyses of Professor Jordan and Palmer for the months from January to June, inclusive, for 1900. The tables that I have prepared are numbered from 53 to 64 inclusive and are reproduced on pages 7374 to 7379, inclusive.

7380 I have prepared a chart from the tables just introduced in evidence, based upon the chemical results of Professors Jordan and Palmer. Such chart, with the caption, "Mean results ,Illinois river Chemical Table, Jordan and Palmer months January to June, inclusive, 1900, L. P. Kinnicutt," is reproduced on page 7381.

7382 From chart No. 2 just introduced, I draw the following sanitary conclusions:

At Joliet, the amount of free ammonia, albuminoid ammonia, oxygen consumed, is not half as great as in 1899, showing much less pollution of the water in 1900 than in 1899. There

is, as in 1900, a rapid fall in the curves representing the amount of free ammonia, albuminoid ammonia, and oxygen consumed, in the stretch of river between Joliet and Ottawa, with corresponding rise in nitrogen as nitrites and nitrates, showing that the active zone of decomposition is as in 1899, in the neighborhood of Ottawa.

There is a slight increase in the oxygen consumed curve between Ottawa and La Salle. The albuminoid ammonia curve remaining nearly stationary, indicating a slight addition of organic matter to the water between Ottawa and La Salle. There is then a steady elimination of organic matter from the river down to Averyville, as shown by the gradual decrease of the curves for free ammonia, albuminoid ammonia, nitrogen as nitrites, oxygen consumed, with an increase of nitrogen as nitrates. The curve of free ammonia does not rise between Averyville and Wesley City, but the rise is noticed between Wesley City and Pekin. This may be due to the fact that the decomposition of the nitrogenous matter did not begin quite as quickly in 1900 as in 1899. The slight delay, a delay represented by about nine miles on the river, being probably caused by the lower temperature of the water in the winter and spring months of 1900, and it is also to be noted that the increase in the albuminoid ammonia curve continues down to Pekin, while in 1899 the decrease began between Wesley City and Pekin. From Pekin to Havana, there is a gradual decrease in the organic nitro-

7383 genous matter, as shown by the free ammonia and albuminoid ammonia curve. From Havana to Kampsville the free and albuminoid ammonia increased very slightly and then decreased to Grafton. The nitrogenous nitrites and the oxygen consumed also rise slightly from Havana to Beardstown, then decrease between Beardstown and Grafton. The nitrogen as nitrites increased continuously from Havana to Grafton. The purification of the river from Havana to Grafton is indicated on the curves by the gradual increasing amount of nitrogen as nitrates. The decrease in free ammonia and albuminoid am-

monia not being so evident on account of spring thaws and freshets.

Taking the two charts together—No. 1 and No. 2—I draw the following sanitary conclusions:

The curves on the chart representing the river from June to January, 1899, closely resemble the curves given on the chart representing the river from January to June, 1900, showing that the general character of the purification that took place is the same for the two years, the small differences being chiefly due to the effect of dilution and to seasonable variations that take place in the river. Both charts show by the rapid decrease of free ammonia, albuminoid ammonia and oxygen consumed, and increase of nitrogen as nitrites and nitrates, the purification that takes place between Joliet and Ottawa, in both years, and that the zone of the most active decomposition of organic matter has not been shoved, or been pushed further down the river by the increasing volume of the river, due to the opening of the sanitary canal. The purification is then shown to continue in both years as the river flows to Averyville, as shown by the decrease in the free ammonia, albuminoid ammonia, oxygen consumed and nitrogen as nitrites. The chart for June to January, 1899, shows by the slight increase in albuminoid ammonia and oxygen consumed between La Salle and Henry that a certain amount of organic matter enters the river at this point, but the continued decrease of free ammonia and nitrogen as nitrites indicates that it is either not very large in amount, or of a character not easily decomposed. In both periods between La Salle and Henry, the nitrogen as nitrites shows a slight decrease, the nitrogen as nitrates also decreasing. The decrease of nitrogen as nitrates at this point is probably due to algae or green plant life. Between Henry and Averyville, the nitrogen as nitrites still decreasing, the nitrogen as nitrates shows an increase more marked between January and June, 1900, than between June and January, 1899. The reason for less increase in nitrogen as nitrates between Henry and Averyville between June and January than between January and June, is due to the larger

7384

amount of green plant life living in river waters in the summer and autumn months, than in the winter and spring months. The rise in free ammonia, albuminoid ammonia, and oxygen consumed, between Averyville and Wesley City show the pollution which enters the river between these two points in both years, which is removed in both years, as shown by the decrease in these substances as the river flows downward to Grafton. The river in both years, as shown by the curves, purifies itself again between Wesley City and Grafton, as it did between Joliet and Averyville.

The slight rise in free and albuminoid ammonia between Beardstown and Kampsville from January to June, 1900, is probably due to seasonal variations, as the river and pond waters contain more free albuminoid ammonia in the winter and spring than at any other time. In the lower stretches of the river in 1899 we find by the charts decreasing nitrites and nitrates; in the chart for 1900, we find, however, that while the nitrites decrease, the nitrates increase. This difference in nitrates in the lower stretches of the river is due to green plant life. This green plant life being more abundant in the summer and autumn months of 1899 than in the winter and spring months of 1900, removed, therefore, the nitrates to a much larger extent in 1899 than in 1900.

I have prepared a chart based upon the bacterial tables of Professors Burrill and Jordan for the months of May to December, inclusive, for 1899.

7385 The chart, with the caption, "Mean results, Illinois river, Bacterial Table, Burrill and Jordan," Months of May to December, inclusive, 1899, L. P. Kinnicutt, is reproduced on page 7386.

7387 The study of this chart, in connection with the chart for the chemical data of the same period, show a striking agreement between the chemical and bacterial data. The bacteria, which number over 1,000,000 per c.c. at Joliet, decrease very rapidly to La Salle. In this distance, of about 62 miles, the number has fallen from 1,000,000 to 17,412 per c.c. This shows,

as did the chemical results, that the zone of the greatest purification is near Ottawa. There is a slight rise in the number of bacteria of only 2,000 per cubic centimeter between La Salle and Henry, a rise coinstant with the rise for albuminoid ammonia in the chemical chart for the same period. From this point the number falls steadily until Averyville is reached, the number there being 4,756 per cubic centimeter. Then on account of the pollution entering the river at Peoria, the number rises immediately to 995,503. This sudden rise in the number of the bacteria shows how quickly sewage pollution can be detected by bacterial examination. From this point the number of bacteria rapidly falls and at Kampsville there are only 7,457 per cubic centimeter, showing the great amount of purification that has taken place between Wesley City and Kampsville. Between Kampsville and Grafton there has been, as was the case between La Salle and Henry, a very slight increase in the number of bacteria, 2,005 per cubic centimeter. This increase is not at all significant, as a slight increase at this point, after the rapid decrease between Wesley City and Kampsville is absolutely without significance as regards the problem of stream purification.

7388 I have prepared a chart based upon the bacterial tables which I have prepared from tables of Professors Burrill and Jordan, already introduced, for the months of January to June, 1900. The chart, with the caption, "Mean results, Illinois river, Bacterial tables, Burrill and Jordan, months January to June, inclusive, 1900, L. P. Kinnicutt," is reproduced on page 7389.

7390 This chart shows the amount of bacteria at Joliet to be about 900,000 per cubic centimeter, falling to 110,000 at Ottawa, showing that the greatest amount of purification took place, exactly as it did in 1899, in the neighborhood of Ottawa. Between Ottawa and La Salle there is a slight increase in bacteria, corresponding to the slight increase in the oxygen consumed, as shown in the chart representing the chemical data for this same period. From Ottawa to Averyville the number of

bacteria rapidly decreases until at Averyville one cubic centimeter contains about 45,000 bacteria. At Wesley City there is an increase in bacteria amounting to 60,000 and which continues to increase until Pekin is reached. This increase, due to pollution, was shown in the curve for albuminoid ammonia, in the chart representing the chemical curves for the same period. The rapid purification in the spring months does not begin until after the river passes Pekin. From Pekin to Havana the curve falls rapidly, showing that great purification has taken place. From Havana to Beardstown there is an increase in bacteria, followed by a quick decrease, the number at Kampsville being only about 40,000. From Kampsville to Grafton there was, as in 1899, a slight increase in the number of bacteria, but the number at Grafton is less than at Averyville, showing the removal of the polluting material entering the river at Peoria. As was to be expected, the number of bacteria in the lower stretches of the river, as shown by this curve, is greater during the summer and autumn months of 1899, than in the spring months of 1900. The soil bacteria washed into a stream during the late winter and early spring months, always increases largely the number of bacteria in a river during that period.

7391 I have prepared tables showing comparisons of the sanitary character of the tributaries of the Illinois river, based upon the chemical results at their mouth, with the Illinois river at Grafton, based upon the tables of Professors Jordan and Palmer, for the months of June to December, inclusive, 1899. These tables were prepared in the same manner as the other tables I have introduced. Tables numbered from 65 to 72 inclusive, are reproduced on pages 7391 to 7395 inclusive.

7395 I have prepared a chart based on the tables which I have just introduced. The chart, with the caption, "Mean results, Comparison of the Sanitary Character of the Tributaries of the Illinois river at their mouths, with the Illinois river at Grafton, Professors Jordan and Palmer, months of June to

December, inclusive, 1899, is reproduced on page 7396 of record.

7397 The chart requires very little explanation, as it is seen by the eye, that the waters of the Des Plaines, the Kankakee, the Fox at their mouths, the Mississippi at Grafton, the Missouri at West Alton, contained in 1899 as much or more albuminoid ammonia and oxygen consumed than the Illinois at Grafton. The higher nitrogen as nitrates in the Illinois river, shows that the Illinois river at Grafton contained at one time higher up on the stream more organic matter, which has undergone decomposition, than did the other rivers. The free ammonia and nitrogen as nitrites is slightly higher in the Illinois at Grafton than in these other streams mentioned, with the exception of the Sangamon, but the amount in the Illinois is low, about 0.23 parts free ammonia and 0.047 parts nitrogen as nitrites, and is without any particular significance. As regards the purity of these streams, as shown by chemical charts and data, and by these curves, I should say that the waters of these various rivers were about in the same condition in 1899 as the Illinois river at its mouth, with the exception of the Missouri river at West Alton, which contains more organic matter.

7398 I have prepared a bacterial chart from the same tables which I have just introduced, based upon the results obtained by Professors Jordan and Burrill, for the months of June to December, 1899. The chart, with the caption, "Mean results, Comparison of the number of bacteria in the tributaries of the Illinois river, at their mouths, with the Illinois river at Grafton, Burrill and Jordan, months of June to December, inclusive, 1899, L. P. Kinnicutt, is reproduced on page 7399 of record.

7400 This chart shows that the Des Plaines river at its mouth contains about 6,000 more bacteria per c.c. than the Illinois river, at Grafton, while the Missouri river, at West Alton, contains about 7,000 more bacteria per cubic centimeter than does the Illinois at Grafton, the Kankakee, the Big Vermilion and the Sangamon rivers, from one to 2,000 less bacteria

per cubic centimeter than the Illinois river at Grafton, while the Fox, and the Mississippi at Grafton, about four thousand fewer bacteria to the c.c. than the Illinois at Grafton.

As to the condition as shown by the number of bacteria, the Des Plaines and the Missouri would seem to be in a less satisfactory condition, and the Fox and the Mississippi rivers at Grafton in a slightly better condition than the Illinois at Grafton from May to December, 1899. There appears to be not any great difference in this respect as regards the condition of the Kankakee and the Sangamon rivers, at their mouths, and the Illinois river at Grafton.

I have prepared tables based upon the mean results of Professors Jordan and Palmer of the tributaries of the Illinois river at their mouths with the Illinois river at Grafton for the months of January to June, inclusive, 1900.

These tables are numbered 73 to 80 inclusive, and are reproduced on pages 7401 to 7405, inclusive.

7405 I have prepared a chart based on the tables just introduced. The chart, with the caption, "Mean results comparison of the sanitary character of the tributaries of the Illinois river at their mouths with the Illinois river at Grafton, Jordan and Palmer, months January to June, inclusive, 1900, L. P. Kinnicutt," is reproduced on page 7405.

7407 This chart shows that the Mississippi at Grafton and the Missouri at West Alton contained from January to June, 1900, more albuminoid ammonia and oxygen consumed than the Illinois river at Grafton, that the Des Plaines, Kankakee and the Fox contained nearly the same amounts and the Big Vermilion and the Sangamon rivers at their mouths less amounts. Or, in other words that the Mississippi at Grafton and the Missouri at West Alton contained more undecomposed organic matter than the Illinois at Grafton; that the Kankakee and the Fox contained about the same amounts and the Big Vermilion and the Sangamon less undecomposed organic matter. The free ammonia in all the streams is higher than in the autumn of 1899, but the relative ratios is not greatly changed, and in the autumn

of 1899 as in the spring of 1900 the Illinois at Grafton contained more free ammonia than its tributaries. The nitrogen as nitrites is much less in the Illinois at Grafton in 1900 than in 1899, .027 parts against .047 parts, while the amount in the Mississippi, the Missouri, the Des Plaines and the Big Vermilion is about the same in the two different parts of the year.

I have prepared charts comparing the number of bacteria in the tributaries of the Illinois river at their mouths with the Illinois river at Grafton, based upon the bacterial results of Burrill and Jordan for the months of January to June, inclusive, 1900, as they appear in the tables 73 to 80, inclusive, which have just previously been introduced in evidence.

7408 The chart, with the caption, "Mean results, comparison of the number of bacteria in the tributaries of the Illinois river at their mouths with the Illinois river at Grafton, Burrill and Jordan, bacteria per c.c. of water for the months of January to June, inclusive, 1900, L. P. Kinnicutt," is reproduced on page 7409.

7410 This chart shows that the Missouri contained more bacteria during these months than the Illinois at Grafton. The other rivers all contained a less amount per c.c. than the Illinois at Grafton. The difference in this respect between the Mississippi at Grafton and the Illinois at Grafton, however, is not great. The bacterial contents of the rivers is 3 to 4 times greater than during the period in June to January, 1899. This was to be expected as this chart shows the number of bacteria during the late winter and spring months, during which period a greater number of saprophytes or soil bacteria are brought into into the river by thaws and spring freshets, and on this account the total number of bacteria does not give as good an idea as to the sanitary character of the water of the rivers as the chart in the autumn months.

I have prepared tables based on the chemical results of Professors Jordan, Long and Palmer for the months of May, June, July and August, for the years 1899 and 1900. (Witness states

how these charts were prepared and what was taken into consideration in preparing the same.

7411 In accordance with the above description I have obtained the tables 1 to 24, inclusive, which give the mean of Jordan's, Long's and Palmer's results for May, June, July and August, 1899, being tables 1 to 12, inclusive, and the mean of Professor Jordan's, Long's and Palmer's results for May, June, July and August, 1900, being tables 13 to 24, inclusive.

Said tables are reproduced on pages 7412 to 7423 inclusive.

7424 I have prepared two charts of the tables just read in evidence, No. 1 to 24, inclusive. The two charts, with the caption, "Mean results, Illinois river, Chemical Table, Jordan, Long and Palmer, months of May, June, July and August of years noted, L. P. Kinnicutt," are reproduced on pages 7425 and 7426.

7427 Taking the two charts together, I draw the following sanitary conclusions from same:

The resemblance of the various curves for 1899 and 1900 show that the general process of purification took place in the same way after the opening of the canal as before it was opened. It is also to be noted that with the exception of the curves representing suspended solid matter, suspended oxygen consumed and nitrogen as nitrates, that the curves for 1900 are below the curves for 1899, showing that in 1900 a given volume of the river contains less organic impurities than in 1899.

To go more into detail in regard to these data, it is seen that the curves for the total soluble and suspended matter fall between Joliet and Morris, and that this fall is more marked in 1899 than in 1900, on account of the large amount of solid matter contained in the river in the former year. Between Morris and Ottawa there is very little change as regards the solid substances in the river. Also between Ottawa and La Salle the curves for total solids and soluble solids show that there is comparatively little change in the amount of these substances between these two places. The curve for 1899 for suspended solids

rises between Ottawa and Henry and the curve for 1900 for suspended solids rises between La Salle and Henry, both curves falling again between Henry and Averyville. [illegible] Averyville and Wesley City the curves in both years show an
7428 increase in the solid matter in the river. It is shown from the curve representing albuminoid ammonia to be of an animal and vegetable character.

From Pekin to Grafton the curves show very little increase or decrease in total substances in the river, but the curves for solid substances while showing little change for 1900 shows a slight decrease in 1899. In both years the curves show an increase in the suspended matter in the lower stages of the river, but that this matter is mineral rather than organic is shown by the curve representing oxygen consumed, which runs almost a straight line from Havana to Grafton. The curve representing oxygen consumed shows a large amount of organic matter at Joliet which they show is removed to great extent in both years before the river reaches Morris.

Between Averyville and Pekin the rapid rise in these curves shows an increase in organic matter between these points, and the decrease in the curves between Pekin and Grafton shows a removal of organic matter taking place in exactly the same way in both years.

The curves representing the free and albuminoid ammonia show a very large amount of organic matter in both years at Joliet, a sharp decrease to Ottawa and then a gradual decrease to Averyville.

The curves, especially the curve representing the albuminoid ammonia rises slightly between Averyville and Pekin, showing the effect of a pollution at Peoria, and then both gradually falling until Grafton is reached, where the minimum amount of both free and albuminoid ammonia is shown by the curves to be present.

The nitrogen curves, especially the nitrogen as nitrites, show that the zone of greatest decomposition in the upper stages of the river, in both years, is in the neighborhood of Ottawa, and

that the added volume due to the opening of the sanitary canal has not pushed this zone of decomposition further down the river. Beyond Averyville the rapid rise in the curve for free albuminoid ammonia, nitrogen as nitrites, and the decrease in the curve for nitrates, show the addition of polluted waters in both years at Peoria. This, as shown by the curves is
7429 more marked in 1899 than in 1900. The effect of this pollution is shown by the curves to extend to some degree to Havana, but at Grafton, the only curve to show that the water has been polluted at Peoria, is the nitrogen as nitrates.

The curves also show that a given volume of the river water contained less organic nitrogenous matter in 1900 than in 1899.

The chlorine curve gives an idea of the amount of dilution that took place in the flow of the river from Joliet to Grafton.

I have prepared a chart based upon the bacterial results of Professors Zeit, Burrill and Jordan as contained in the tables 1 to 24 inclusive, already introduced into evidence.

Chart with the caption, "Mean results, Illinois river, bacterial table, Zeit, Burrill and Jordan. Months of May, June, July and August of the years noted. L. P. Kinnicutt," is reproduced on page 7430.

7431 From this chart, I draw the following sanitary conclusions:

Both curves show a great number of bacteria per c.c. at Joliet. They then show a great decrease between Joliet and La Salle, a distance of 65 miles. The curves for 1899 show that between La Salle and Henry the number of bacteria increase rapidly, owing principally to the sewage of La Salle and Peru, but decrease almost as rapidly between Henry and Averyville.

The curve for 1900 shows also a slight increase from bacteria between La Salle and Henry and also a further increase between Henry and Averyville, due probably to some local cause. Between Averyville and Wesley City the two show an increase of bacteria in both years, greater, however, between Wesley City and Pekin, in 1899 than in 1900. In both years the curves show a very great decrease between Wesley City and Havana, a dis-

tance of 40 miles, and the decrease continued though not so rapidly between Havana and Beardstown.

The curve for 1900 shows this decrease continues to Kampsville, while the curve for 1900 shows a rise between Beardstown and Kampsville. In both years they show an increased number between Kampsville and Grafton. The curve shows only three places in the river where the bacteria was greater in 1900 than in 1899, namely, at Averyville, Havana and Beardstown. The number of bacteria at Grafton is shown to be about 6,000 less per c.c. in 1900 than in 1899.

I have prepared tables based on the analytical data of Professors Jordan and Palmer, on the tributaries of the Illinois river at their mouths, with the Illinois river at Grafton, for the months of May and June, 1899 and 1900. These tables are numbered 25 to 40 inclusive, and are reproduced on pages 7432 to 7440, inclusive.

7440 These tables were prepared in the same manner as the other tables referred to. I also prepared a chart based on the tables just read in evidence.

The chart with the caption, "Mean results, comparison of the sanitary character of the tributaries of the Illinois river at their mouths, with the Illinois river at Grafton, Jordan and Palmer, months of May and June, 1899 and 1900, L. P. Kinnicutt, reproduced on page 7441.

7442 The chart just introduced shows in the first place that the Illinois river at Grafton contains much less organic impurity in May and June, 1900, than it did in the corresponding months of 1899. The nitrogen as free and albuminoid ammonia, nitrogen as nitrites and the oxygen consumed was less in these months of the year 1900 than the corresponding months of 1899. With the exception of the Big Vermilion all the tributaries to the Illinois and the Mississippi at Grafton contain more nitrogenous organic and easily oxidizable matter during May and June, 1899, than did the Illinois at Grafton during the same months. It is also seen to be the same for 1900, that is during May and June of 1900, excepting the Big Vermilion all

the tributaries to the Illinois and also the Mississippi at Grafton and the Missouri at West Alton contained more nitrogenous organic and easily oxidizable matter than did the Illinois at Grafton during the same period. The chart also shows that during June, 1899, the Illinois contained more nitrogen as free ammonia, than did its tributaries during the same months, but during May and June, 1900, it is seen that it contains less
7443 than the Des Plaines, the Kankakee, the Fox and the Big Vermilion and practically the same amount as the Missouri.

In May and June, 1899, the Illinois contained more nitrogen as nitrites than any of its tributaries excepting the Fox and the Sangamon.

In May and June, 1900, it contained less than the Big Vermilion, the Sangamon nad the Des Plaines.

I have prepared a chart based upon bacterial results of Professors Burrill and Jordan for the months of May and June, 1899 and 1900 which results are in the tables which I have just introduced. Said chart is reproduced on page 7444 of the record.

7445 This chart shows that the Illinois river at Grafton during the months of May and June, 1899, contained over 10,000 more bacteria per c.c. than during the same months of 1900. It also shows that the Illinois river at Grafton, during the months of May and June, 1899, contained more bacteria per c.c. than did any of its tributaries, and more than the Mississippi at its mouth, during the same months.

During May and June of 1900, the Illinois river at Grafton contained, excluding the Fox river, not only less bacteria per c.c. than any of its tributaries, less than the Mississippi at Grafton and the Missouri at West Alton, during the same months in 1900, but also contained a less number of bacteria than did any of its tributaries with one exception, the Big Vermilion, during the corresponding months of 1899. The Missouri at West Alton is shown by the chart to contain over 40,000 more bacteria per

c.c. during May and June, 1900, than the Illinois at Grafton. The Illinois at Grafton containing only 8,740 per c.c.

There were no data from which the number of bacteria contained in the Missouri at West Alton in May and June, 1899, could be determined. The Missouri at West Alton during the months of May and June, 1900, was from bacterial representations, much more polluted than the Illinois at Grafton.

7446 The reason that I took the mean was because it is my opinion that in taking a mean of the analytical data obtained by the various observers at the various stations on the Illinois river more accurate information can be obtained of the changes that take place in the river than by studying the data of any one person.

Further, I did this because it is a method commonly employed in all scientific investigations, as for instance what are now considered as the figures representing the correct amount of hydrogen and oxygen in water were obtained not from the results of a single observer but by combining the data of many different experiments made by many different observers.

The tables and charts which I have offered in evidence show that the sewage of Chicago, as it enters from the sewers into the drainage canal undoubtedly contains a small amount of oxygen and the first action that takes place is undoubtedly anaerobic action in which part of such substances like urea are decomposed, ammonia being given off. The action in the sanitary canal is an anaerobic action, or very similar to that which takes place in the septic tank. By this action about 20 per cent of the organic matter as measured both by the loss in the albuminoid ammonia and by the loss in oxygen consumed is removed

7447 from the sewage. Also a certain amount of suspended matter is removed and a certain amount of suspended matter has been rendered soluble and a certain amount has been converted into gases and into simpler products.

By this action the sewage is not only purified, but changed so that further purification will take place more easily. The next stage in the purification is the aerobic stage. Undoubtedly

in the upper stretches of the river near Joliet we have both aerobic and anaerobic action taking place. Further down as at Ottawa we have principally an aerobic or nitrifying action. At about this point both in 1899 and 1900 is the zone of greatest decomposition. From this point the action, in my opinion, is entirely anaerobic or nitrifying action continued purification going on until we come to Averyville.

Between Averyville and Wesley City the tables and diagrams that I have made show that a large amount of organic polluted matter is added to the river. At Pekin or between Peoria and Pekin, we have also again more or less anaerobic action with aerobic action taking place.

The purification continues and between Pekin and Havana the action that takes place is aerobic or a nitrifying action. The aerobic purification then goes on until at Grafton, all the original organic matter which was in the sewage at Pekin has been decomposed and changed.

The effect of emptying the sewage of Chicago into the drainage canal into the Des Plaines river at Joliet and then into the Illinois river is to increase the amount of organic matter in the upper stretches of the river.

The effect, however, of adding this organic matter to the upper stretches of the river is not noticed at Averyville except in the increased nitrogen contents of the river and the high chlorine and the same can be said at Grafton, at the mouth of the Illinois river. At that point the effect of the addition of the sewage to the Illinois river is seen only in the high chlorine and

the nitrogen as nitrates. This nitrogen content of the

7448 river is very different from the nitrogen content of the river at or above Ottawa. It is nitrogen which has been changed over and over again from the original character in which it occurred at Joliet. How this change takes place I have tried to show in my description of the nitrogen cycle. These charts also show that the purification of the river in the two years took place exactly in the same way and also that the river at all points was purer during May, June, July and August in

1900 than in 1899. My opinion is, as has been shown by my answers to the previous questions, that I believe that the sewage of Chicago is entirely decomposed before Grafton is reached, and that the only effect that we perceive in the river at Grafton, is the nitrogen contents and in high chlorine. The nitrogen contents and the chlorine, such as are found in the river at Grafton, are not in themselves elements dangerous in the slightest degree, to public health. They have, so far as we know, absolutely no effect upon the human system. I have studied the coli determinations as given by Professor Jordan in Streams Examinations, also his coli determinations made in 1901, and introduced in evidence in this case. I have acquainted myself with the experiments made upon the viability of the typhoid germ by Professors Jordan, Zeit and Russell.

7449 Taking into consideration all the data that I have presented and all the data that I have studied regarding the Illinois river, and assuming that you mean by deleterious matters any matters that were in the sewage of Chicago that were deleterious to human health, and by infectious matter that you mean typhoid bacilli, I do not believe that they reach down the Illinois river as far as Grafton.

My reasons in full for this answer are that in my opinion all of the deleterious substances which may have been considered to have been contained in the Chicago sewage meaning by deleterious substances not bacterial life, have been entirely decomposed and rendered absolutly harmless long before

7450 the river reaches Grafton, and that the infected matter, meaning by that typhoid bacilli, which enters into the drainage canal from the sewage of Chicago would not survive the passage from Chicago to Grafton.

All of the data that I have presented show that the Illinois river at Grafton does not contain undecomposed matter derived from the sewage of Chicago and it is my opinion that the typhoid bacilli from Chicago would not survive the journey from Chicago to Grafton, and therefore it is my opinion that the

water of the Mississippi river west of the center of the main channel of said river below the mouth of the Illinois river and down to the intake tower of the St. Louis water works at the Chain of Rocks, is not less valuable for drinking purposes and not more liable to carry water-borne diseases, such as typhoid fever and cholera, now than it was before the sewage from the sanitary district of Chicago was run into the drainage

7452 canal. My opinion is that the typhoid fever could not live for weeks or months or even years in gradually diminishing numbers in a sewage polluted stream, for all the experiments with which I am familiar show that the typhoid germ will live a less time in a polluted water than in a pure water.

From the experiments that have been made I do not believe that the typhoid bacilli would live until it entered the slack waters at Peoria, and even assuming that it would survive the passage from Chicago to Peoria, and be deposited in the bed of Lake Peoria for a period of a month, I do not believe that it would live for a period of a month in such a deposit, and in this connection I would like to call attention to the experiments made by the Massachusetts State Board of Health, which are reported in the 34th Annual Report of the Massachusetts State Board of Health in which the experiments of Mr. H. W. Clark and Stephen DeM. Gage are given.

(Witness refers to experiments made by investigators in reference to the viability of bacilli coli, in order to sustain the above answer.)

From all the data that I possess and from all the knowl-

7453 edge that I have acquired regarding the life of the typhoid bacilli, I do not think it is possible that the waters leaving Lake Peoria would contain at times more infectious and dangerous pollution than is at present in the polluted sewage entering at the Bear Trap dam at the foot of the drainage canal.

I am very firmly of the opinion that the waters of Lake Peoria can not at any time contain as much infectious and dangerous material, as the waters at Bear Trap dam, and I know

absolutely of no data that would warrant any such assumption.

Knowing the character of the Illinois river and bearing in mind the amount of sedimentation, the amount of dilution and the amount of purification that occurs between Chicago
7454 and Grafton and especially bearing in mind the time element, I do believe that the time interval would render the Mississippi river water at all times free from liability of producing water-borne diseases from pathogenic bacteria entering the Illinois river by way of the drainage canal. It being my opinion that typhoid fever bacilli from Chicago entering the Illinois river do not survive the journey from Chicago to Grafton.

7455 I can find no evidence that shows that the typhoid bacilli does or can pass from Chicago out into the Illinois river, thence to the Chain of Rocks and the intake tower at St. Louis.

From all the data that I have studied, and from all the knowledge that I have been able to obtain regarding the Illinois river I find not the slightest evidence that the Illinois river, containing the mixed sewage and canal water from the Chicago drainage district since the opening of the drainage canal renders the waters of the Mississippi river below the mouth
7456 of the Illinois river less safe and wholesome than it was before the opening of the canal, for drinking purposes on the part of the inhabitants of Missouri.

From various experiments that have been made it has been shown that the vitality of the typhoid bacilli is greater in pure water than in water polluted by sewage, and basing my opinion on these facts, it is my opinion that the sewage from Chicago does not favor the longevity or growth of germs from Peoria or anywhere else emptying their sewage into the Illinois river.

7457 It is absolutely necessary to employ both chemistry and bacteriology, and it is impossible to form a correct judgment as to the quality and the potability of a water without the aid of both of these sciences.

From all the tables that I have studied and the various analyses that have been made upon the waters of the Illinois river, all indicate that the zone of the greatest decomposition in both 1899 and 1900, before and after the sanitary canal was opened in the upper stretches of the river was in the neighborhood of Ottawa. In the lower stretches of the river there is in both years another zone of decomposition somewhere between Pekin and Havana.

7459 From my knowledge of the Illinois river, flowing as it does at high water over a very large amount of territory, and the fact that the river is studded with lakes, nearly all the way from Upper Peoria to its mouth, I do not believe that even at the different stages of water of the Illinois river, the sewage from the city of Chicago, passing through the drainage canal into the Illinois, at different seasons of the year, would be a danger or a menace to the inhabitants of Missouri and the citizens of the city of St. Louis, using the water of the Mississippi river at the intake tower, at the Chain of Rocks.

From the chemical and bacterial analyses introduced in evidence by Professors Long, Palmer, Burrill and Jordan, together with my study of the tables and charts that I have prepared and introduced as evidence, it is my opinion that the Mississippi and the Illinois rivers practically contain about the same amount of impurity, while the Missouri river contains a larger amount of impurity than either of the other two rivers named.

7460 It is my opinion as a sanitary expert and with a knowledge of conditions that obtain in and along the Illinois river, and from the evidence that has been submitted in this case, that such infected matter or pathogenic germs which come into the drainage canal from Chicago, do not reach as far down the Illinois river as the city of Grafton.

7461 In my opinion, the only effect the pollution and contamination from the sewers of Chicago, entering into the Chicago river, thence into the drainage canal, that could be noticed

at the Chain of Rocks on the Mississippi river, is a higher chlorine and nitrogen contents of the river.

7462 It is a well known fact that the larger amount of surface over which the water spreads, the greater will be the amount of deposition, consequently the increased water at flood times, causing a larger area of land to be overflowed along the Illinois river, would tend to cause a greater deposition of the suspended matter coming from the sewage of Chicago and entering the Illinois river through its canal.

From the examinations that have been made, and the finding of the coli bacilli in the majority of one cubic centimeter samples, I do not believe that the Mississippi river at the Chain of Rocks was prior to 1900, a safe and potable drinking water, fitted for domestic and drinking purposes in its raw state. Same as to the Illinois and Missouri river waters.

7463 It is my opinion all the examinations that I have studied, as well as my own tables and charts show, that the waters of the Illinois river at Grafton are in a purer state since the opening af the drainage canal.

They are certainly not less sanitary than the waters of the Mississippi river, and they are in a better sanitary condition, as shown by the bacterial and chemical analyses than the waters of the Missouri river.

AT STAFFORD HOTEL, BALTIMORE, MD., March 26, 1904.

7465 WILLIAM S. THAYER, Examined in chief by Mr. Todd:

7466 Am a physician. Reside in Baltimore. I am one of the physicians in chief of the Johns Hopkins Hospital Dispensary, associate in medicine at the Johns Hopkins Hospital, associate professor of medicine in the Johns Hopkins University and visiting physician to the Union Protestant Infirmary. Have given special study to the so-called germ fevers

in regard, particularly, to malarial and typhoid fever. (Gives clinical diagnoses of typhoid fever.)

7469 I published a number of papers prior to 1900 and in that year I published a text book, "Lectures on the Malarial Fevers."

7470 (States what is malarial fever and its clinical diagnoses.)

7471 The only known way by which malaria can be carried is by the bite of a mosquito.

7473 (States what intermittent, remittent, typho-malarial, congestive and simple continued fevers are.)

7475 Remittent, intermittent, typho-malarial, congestive and simple continued fevers are not distinct types of disease and are not so recognized by bacteriologists and clinicians. They are simply terms describing symptoms. When these terms appear in vital statistics as applied to fevers, I should regard them as representing, in the vast majority of cases, typhoid fever. (Table showing deaths from typhoid fever in one column and from remittent, etc. fevers, in another column from 1890 to 1903, inclusive, in the city of St. Louis, read to witness.) I should say unquestionably that the deaths reported as occurring from typhoid fever alone in the city of St. Louis do not properly represent, in my opinion the total number of typhoid deaths actually occurring in that city.

7476 I should say in the first place that a considerable personal experience with cases in which these very diagnoses have been made, has shown me that in almost every instance they represent typhoid fever. I should say furthermore that in an experience of fourteen years in the Johns Hopkins Hospital—I have never made, and I know that there does not stand on the books a single diagnosis such as appears in the list which you gave of the remittent, typho-malarial fever and so forth; and further from the fact that the deaths from malarial fever itself in this city and in this neighborhood which is a malarious neighborhood, occur in extremely small proportion as compared with those of typhoid fever—I should say that in view of all these facts as well as in view of the fact that in other cities in which these diagnoses used to be made, they have now been

abandoned entirely, these cases all being classed as typhoid fever—in view of all those facts I should feel perfectly certain in my own mind that the great majority of those cases represent typhoid fever.

7477 I should attribute the failure of those statistics to properly disclose the number of typhoid deaths occurring in St. Louis, to wrong diagnoses made by physicians in reporting deaths. (Witness states why doctors employ the terms "remittent, etc. fevers" for fevers that are recognized as being either typhoid or malarial.) (Witness compares statistics of typhoid malarial fevers in the cities of New York, Brooklyn, Philadelphia and Baltimore.)

7482 As one compares these statistics with the statistics of St. Louis, it will be found that those of Brooklyn show at certain times even a larger proportion of the so-called malarial fevers than were present in St. Louis, but that the same change has taken place here as has occurred in St. Louis—the diagnoses of malaria have diminished, and the diagnoses of typhoid fever relatively increased.

I should say that a perfectly safe estimate would be at least seven-eights of the deaths reported under the heading of remittent, etc. fevers, which should be placed in the column of typhoid deaths.

If one desired to get the relevant frequency of typhoid fever from year to year I think that the adding together of the two columns would give as correct an idea as any other method.

It is recognized by all competent observers that reporting deaths to the Health Department by placing typhoid fever in one column and remittent, etc. fevers in another, is entirely incorrect.

7484 (Table read to witness showing typhoid death rate by months, under column A, and death rate from remittent, etc. fevers, under column B from the year 1895 to the year 1903 inclusive, by months.)

7485 I should regard these tables as indicating that the mortality from typhoid fever had fluctuated more or less from year to year. That gradually in the last three years an

improvement in the accuracy of the reports from the general physicians had taken place so that cases of typhoid fever which had previously been included in column B had been properly reported as typhoid fever. As to the relative frequency of typhoid fever and malaria it would seem to me that it would be impossible to draw definite conclusions from these tables, though as to the prevalence of typhoid fever I should think that one might draw good conclusions.

I should think that the mortality from typhoid fever had varied from time to time, from year to year; had risen slightly during the last two years, but that the fluctuations were no more than such as had previously occurred and were not such as to justify any direct assumptions in regard to the cause.

In the year 1892 I should suspect that there had been some definite epidemic, but since that time the variations shown are not such as to suggest to me any striking special cause. They are variations such as occur in most cities in this country from time to time without explanation.

7486 (Table read to witness showing consolidation of deaths from typhoid fever with those resulting from remittent, etc. fevers, as reported to the St. Louis Board of Health.)

I should regard this table as indicating only variations in the typhoid mortality, such as I stated a moment ago might and do occur in many cities without any definite explanation being found.

The typhoid mortality I should say had rather decreased, tended on the whole to decrease from 1893 down to 1901. During the two years following 1901 there has been a slight increase, but that increase is not, it seems to me, more than might occur without any special change in the pre-existing conditions.

Assuming that circular letters were issued in the fall of 1900 and 1901, calling the attention of physicians to the law requiring report of typhoid deaths, etc. I should say that these statistics certainly show the effect of such letters.

It appears in the relative increase in the number of deaths reported in the typhoid column as compared with those in the

column of remittent, intermittent, malaria, congestive and simple continued fevers. It would indicate to me that, stimulated by the advice of the board of health, the physicians had made more accurate and careful diagnoses.

Assuming that in St. Louis in 1895 there were in the neighborhood of 4800 wells, that 50 of those wells were examined and found to be contaminated by the city chemist and condemned; that the board of health passed an order instructing the city chemist to stop the examination of city wells until further orders, I should think that the chances are that such wells would have an effect upon the typhoid conditions of such city and that such wells would be a menace to the health of the city and that it would be very possible that certain of the wells might become infected and serve to spread the disease. (Table read to witness, which was testified to in evidence by Prof. Jordan, compiled from typhoid fever and typho-malarial columns of mortality statistics of St. Louis from the years 1890 to 1900, according to census reports and the intervening years estimated by Farr's Formula.)

7490 I should say this table indicated that during the past two years there has been a slight increase in the typhoid mortality, but that this increase had been preceded by a diminution and on the whole a gradual diminution from 1892 down to 1901.

I should hesitate from these figures to assert that the mortality had permanently increased or I might say that to look at such table I should not regard it as having greatly increased, and I should want to see what happened in 1904 before expressing any opinion.

The increase in 1902 and 1903 seems to me not more than might occur with fluctuations such as are observed in the tables which I have mentioned from New York, Brooklyn and other cities.

7491 Assuming that the typhoid deaths as reported in the typhoid fever column for the city of St. Louis are correct and that in 1899 the increase over 1898 was 34.7 per cent, and

in 1900 the increase over 1899 was 25.3 per cent, and in 1901 the increase over 1900 was 14.7 per cent, and in 1902 the increase over 1901 was 9.5 per cent.

7492 It seems to me that the conditions between 1898 and 1899 are worse than those between 1900 and 1901.

7493 I should not consider the conditions in the last several years in St. Louis, such as to suggest that any striking change had taken place in the general conditions that obtained prior to that time, as regards typhoid fever.

7494 CROSS-EXAMINATION, By Mr. Jeffries:

Assuming that a patient takes ill with fever and remains so for several months and finally dies, and the death is reported as intermittent or remittent fever, I should, if that case had been treated with quinine, and the fever had not broken, assume that it certainly was not malarial fever.

7502 AT CITY HALL, PHILADELPHIA, PA., March 28, 1904.

JOHN W. HILL, Examined in chief by Mr. Todd:

Am a hydraulic engineer. At the present time I am employed by the city of Philadelphia as chief engineer of the bureau of filtration, a bureau that is conducting the general improvement of the water supply of that city.

7505 Have studied chemistry and bacteriology with a view to informing myself as to the true interpretation of the conditions of water I would be required to deal with as an engineer.

7506 I have examined and studied bacterially and chemically the analyses of the water of Lake Michigan, the drainage canal, the Des Plaines river, the Illinois river, the Mississippi river and the Missouri river as made by Professors Jordan, Palmer, Burrill and Long, the same being published as reports of streams examination which have already been introduced in evidence and the reports of Professor Long appearing in the published health reports of the board of health of the State of

Illinois, the same having also been introduced in evidence in this case.

7507 I am acquained with the Chicago river, the drainage canal, the Des Plaines river, the Illinois and the Mississippi river from Grafton to St. Louis, so far as they are represented in public documents and in hydraulic maps published by the United States government and by the city of Chicago. I have not made a personal examination of the drainage canal or of the Illinois river excepting of the Illinois river at Peoria during the year 1882 when I was employed on the Peoria waterworks.

7509 In connection with the work now going on in Philadelphia, I made experiments upon the longevity of the typhoid bacillus in unsterilized Delaware river water, and found that its life history was from five to eight days under the most favorable conditions. This experiment also revealed the fact that the colon bacillus would live longer in the unsterilized Delaware river water with the different degrees of salt than would the typhoid organism. The Delaware river water is a sewage polluted water.

7511 (States how experiment was made as to longevity of typhoid bacillus in Delaware river water.) I have a table showing the results of the experiment just recounted, said table being reproduced on pages 7512 and 7513.

7516 The greatest length of time that a typhoid bacillus lives, as shown by these tables, is eight days. This water was sterilized. I should anticipate that its life in unsterilized water would certainly be no longer than eight days and probably less than eight days. I regard the laboratory experiment as more favorable than conditions in nature, for the longevity of the typhoid bacillus.

7517 From my knowledge of the typhoid bacillus, I should put the life of the typhoid organism in a sewage polluted river water under normal conditions which prevails with the majority of the rivers of the United States drawn on as the sources of public water supply as from 5 to 8 days. I am now

referring to the typhoid organism that would come in from a definite point. That organism would probably be not found in the water at the end of five to eight days.

7518 From such information as I have of the bacteriological and chemical contents of the Illinois river as disclosed in the volume entitled Streams Examination, prepared by the sanitary district of Chicago, and of the physical conditions with reference to slope, of their being slack water pools formed in the river at different points, I should not anticipate a greater longevity of the typhoid organisms in the waters of the Illinois river than I have found in the waters of the Schuylkill and Delaware rivers.

7519 The dams in the Illinois river, in view of the flat slope of the stream bed, would create pools corresponding in numbers to the dams, in which sedimentation is bound to take place.

7520 The percentage of sedimentation would probably be increased during flood periods in the Illinois river. Assuming that there are in the neighborhood of 400,000 acres of land inundated and subject to overflow in the Illinois river, the effect would be to increase the rate of sedimentation during the time when the stream was out of its banks. I do not think that if the maximum flow through the drainage canal was 800,000 cubic feet per minute that the quantity of water mentioned would impede sedimentation but it might diminish the rate at which sedimentation would occur during stream flow.

7521 Dilution of a sewage polluted stream means or should mean dilution with purer water than that flowing in the stream. It operates in two ways, first, self-purification, in a mechanical way by increasing the volume of flow in the main stream and reducing the percentage of pollution; next, to increase the rate of oxidation of organic matter by adding to the polluted water a water higher in dissolved oxygen, and it is probable that with reasonable limitations the addition to a sewage polluted stream of a stream of purer water high in dis-

solved oxygen, would facilitate the oxidation of organic matter. The danger of infection is really diminished by dilution.

7522 The water from Lake Michigan improves the quality of the water flowing in the Illinois river. The water flowing into the Illinois river from Lake Michigan should be regarded as a benefit to the Illinois river. (Witness compares tables of 1889 with those of 1900, giving the chemical and bacteriological determinations.) I still think the indications are that the chemical conditions, or at least some chemical conditions, indicate that self-purification is better for the latter year, and having no better data before me than that quoted in the answer, or that mentioned in the question, it does not appear that the addition of the sewage in Chicago has injured the quality of the water of the Illinois river south of Peoria.

7523 The addition of water to the Illinois river from Lake Michigan would increase the current and increase, to some extent, the time required for sedimentation. If the increased volume of water was such as to overflow the banks, it might, upon the whole, have the opposite effect by reason of the large degree of sedimentation that would take place outside of the defined channel of the river on the bottom lands. If, however, it should be shown that the mean velocity of the stream was not materially increased by the addition of water from Lake Michigan it would probably have no marked effect on the rate of sedimentation. The chief factor that would govern in this case would be the mean velocity of the flow of river before and after the addition of water from the lake.

The sedimentation and oxidation of organic matter during stream flow is favored by the low channel and surface slope of the Illinois river as compared to other streams.

7524 Basing an opinion upon the technical investigations that have been made of the water of the Illinois river at Grafton during the four selected months of 1899 and the four corresponding months of 1900 it does not appear that the sewage of Chicago has materially changed the conditions, and such

changes as are shown would indicate from a chemical point of view an improvement in the quality of the water at Grafton, since the opening of the drainage canal.

Basing an opinion on the technical data contained in the book entitled Streams Examination which has been referred to before in my testimony, there is nothing to indicate that the danger to public health has been increased since the opening of the drainage canal. In making this statement I wish it understood that I do not believe that the water flowing in the Illinois river at Grafton before the opening of the drainage canal was fit for drinking and some other domestic uses, and my answer must be construed as showing only that the conditions are no worse during the months of 1900 which I have under consideration than they were during the corresponding months of 1899 prior to the opening of the canal.

7525 Table showing number of bacteria and average of results of chemical analyses for the years 1899 and 1900 at various places at which samples of water were taken during the investigation made by the defendant in this case.

7528 (Witness comments on the tables just introduced, and states.)

7529 Taking all the data together and particularly that relating to the total oxygen consumed, and the nitrates and nitrites, I consider that the condition of the water flowing in the stream at Grafton has been improved.

7530 Basing the opinion upon the technical data collected by others for the purpose of this investigation, I do not think that the sewage of Chicago in its original condition is manifested in the waters of the Illinois river at Grafton. The question of high or low water in the Missouri, at a time when there was high water in the Illinois river, would have no effect on the result at Grafton.

7531 Considering the technical data already referred to in previous answers and contained in the book entitled Streams Examination and considering the relative drainage area of the Illinois river and the Mississippi river above St.

Louis and of the Missouri river, I do not think that any marked effect would be felt in the combined waters of the three rivers by reason of the combined discharge of sewage and Lake Michigan water into the head waters of the Illinois river at Joliet.

I should think that a typical bacillus would perish more quickly in the sediment of a stream than in the water above such sediment. I should not expect a typhoid organism introduced into the Illinois river, together with the sewage of Chicago and Joliet, to pass the entire length of the stream. Upon the contrary I should expect it to perish somewhere in transit and probably before it reached the city of Peoria, and the reason for this opinion is based upon the evident rate of reduction of organic matter in the river between the point of discharge into the canal and the city of Peoria, the typhoid bacillus like other bacteria being a part of this organic matter.

I do not regard the settling basins at St. Louis, as they are at present constituted, a complete guaranty against infection coming from the waters of the Mississippi river.

7533 (Witness gives reasons.) I am acquainted with the settling basins used at Covington, Kentucky, and I do not think that because such basins hold a thirty days' supply of water and typhoid fever should prevail among the people using such water, that the typhoid bacillus will live in that water for such a period. (Witness gives reasons.)

7537 In the interpretation of typhoid statistics of a city, my custom in stating typhoid fever cases and deaths, is to relate the rates to the unit of one hundred thousand population living. The mortality percentage method does not as easily convey to the ordinary mind the true relation of the typhoid fever statistics of the population, as the method of relating deaths or cases to some unit of population, for example 10,000 or 100,000. The mortality percentage method is not regarded, on the whole, as the most accurate among sanitarians and students of vital statistics in ascertaining typhoid conditions of a given community. The danger of infection is not so great from the rural population as from the established centers of urban population

because the opportunities of sewage from the rural population reaching some watercourse are not so great as in established centers where systems of sewage are in vogue.

7539 If upon a watershed where the water is polluted, there should be many sources of pollution and infection and typhoid fever should break out in a given community, I would look for the source of infection at the nearest possible point of pollution above the source of water intake, or above the point of water intake.

7541 Basing an opinion upon the technical data in the volume entitled Streams Examination previously referred to in my testimony I should regard the quality of the water of the Illinois river at Grafton as no worse and in some respects better than the mixed waters of the Illinois, Mississippi and Missouri rivers at the point in the Mississippi river, below Grafton as shown by the data in the tables of technical data previously offered as a part of my testimony.

7542 From a bacteriological point of view the water of the Illinois river at Grafton is decidedly better than the water of the Missouri river at West Alton. Considering the suspended matter the water of the Illinois river at Grafton is superior to the water of the Missouri river at West Alton.

The same statement may be made with reference to total solids.

The same statemnet may be made with reference to the nitrates and nitrites. The degree of nitrification being shown as greater for station 21 at Grafton, at the mouth of the Illinois river than for station 32, West Alton on the Missouri river.

Considering the chlorine alone the water of the Illinois river at Grafton would not be considered as good as that of the Missouri river at West Alton.

7543 (Witness gives figures showing the mean rainfall on the Illinois, Missouri and Mississippi watersheds.

Of the water flowing in the Mississippi river opposite St. Louis, 20 per cent would be credited to the Mississippi river,

75½ per cent to the Missouri river and 2.96 per cent to the Illinois river and 1.54 to the influence of the discharge of the Chicago sewage, or such water as is carried with the sewage into the drainage canal exclusive of the diluting water drawn from the lake. (Witness states information upon which above data is based.)

7545 Table read in evidence showing the drainage basin of the Missouri river.

7547 Same for the Mississippi river.

7548 Same for Delaware river above Trenton, N. J.

7549 Schuylkill river above Philadelphia.

These tables were made by Mr. S. B. North, Director of the census, from the statistics in his bureau, and show the population on each one of the above watersheds. In my opinion, the mixing of the Illinois, with the Mississippi and Missouri rivers does not create any added danger to the already contaminated and polluted waters of the Missouri and Mississippi rivers at the St. Louis intake. The analytical investigations reported on by Professors Palmer and others in Streams Examination and the other in relation to the total flow of the Illinois river, including Chicago sewage and water drawn from Lake Michigan, the first indicating that the condition of the Illinois river at Grafton was no worse during the four specified months of 1900 than the same four months for 1899, prior to the opening of the drainage canal; and the second indicating that the

7550 total volume of flow of the Mississippi river opposite St. Louis by far the smallest percentage comes from the Illinois drainage basin even while considering the flow of the sewage of Chicago and the water from Lake Michigan as a part of the discharge from that river. Under these conditions it would be difficult to conceive of a pollution of the Mississippi river at a point below the confluence of the three rivers of junction of the three rivers, excepting the pollution of the Illinois river was very great with reference to the pollution of the two other

streams which contributed to the body of water moving past the city of St. Louis.

The information which I have with reference to the Illinois river and the quantity and quality of the stream flow, its physical characteristics and the technical data obtained from an examination of the water samples does not warrant the belief that infected matter from Chicago would be found in the Illinois river as far south as Grafton.

If typhoid fever germs were found at the St. Louis intake, it would be wholly impossible, in my opinion, to say what city they were from.

7551 In my opinion, typhoid bacilli could not be deposited on the bottom of the Illinois river and remain there for a period of five years and upwards and then be stirred up by the action of the wind, waves or steamboats, etc., and continue on their journey down to St. Louis. The Missouri, Illinois and Mississippi rivers were not safe waters for drinking and domestic purposes prior to the opening of the canal.

7553 I do not regard any river that receives the sewage of rural and urban populations, as a safe drinking water without mechanical treatment of some kind. Basing an opinion upon the technical data before me, applicable to this question, upon the whole, the condition of the water of the Illinois river at Grafton appears to be improved by the opening of the drainage canal and is not less sanitary than the waters of the Missouri and Mississippi rivers..

7554 There is no evidence before me showing that any such changes occurred in the quality of the water as to render it less desirable for potable purposes, or more deleterious to health than prior to the opening of the canal. If the typhoid fever statistics of St. Louis show an increase since the opening of the canal, unless such increase is co-incident with conditions in Chicago or, in other words, unless the rates in St. Louis showed

that they corresponded with the rates in Chicago, it could not be attributed to Chicago.

7555 The city of St. Charles situated 47 miles from the intake tower of St. Louis, in my opinion, would constitute a greater menace to the water supply of that city than would the larger city of Peoria. (Witness is shown the two charts introduced in evidence by Prof. Mason, and states:)

7557 It does not appear that the typhoid fever death rates from St. Louis are co-incident in intensity with the typhoid fever death rate of Chicago.

This is especially true for the years 1901 and 1902 and 1903. For which years the diagrams show that when the rate is rising in Chicago it is declining in St. Louis and when it is declining in Chicago it is sometimes rising in St. Louis, and that the wide ranges in the typhoid fever death rate as shown in the diagram for the city of Chicago are not reproduced in the diagram showing typhoid fever death rates for the city of St. Louis, and it would not be possible in my opinion to connect the rates in one city with the other.

As a general proposition wells in built up communities like the city of St. Louis, unless they are deep artesian wells or wells driven to a great depth in rock are always open to suspicion as possible sources of illness and disease.

7558 Personally I should regard every such well in the city of St. Louis, the water of which is liable to be used for drinking, as a menace to the public health, excepting the well is so far removed from possible sources of pollution as to be reasonably safe from the contents of vaults and cess pools leeching through the surrounding soil. The water at the Chain of Rocks, in order to be made a safe and wholesome water should be treated by filtration. In passing upon the question of filtering the water at St. Louis, no special consideration would be given the sewage of Chicago running into the head waters of the Illinois river, which forms one of the tributaries of the Mississippi river. (Pages 5960 and 5961, as to the relative values of the Illinois, Mississippi and Missouri watersheds respectively,

as sources of water supply for the city of St. Louis, population per square mile, etc.)

7563 I have considered the total drainage area of each of the three drainage basins. That is I have considered the urban and total population on each of the drainage basins and I have finally developed the factor in the manner explained in the answer to the previous question, which in my opinion shows the relative advantage or disadvantage of the source of water supply of the three rivers mentioned with respect to the three cities drawing their water supply wholly or partly from the sources under consideration. The size of the numbers thus obtained indicates the objection to each source of water supply as follows: For the city of St. Louis on the assumption that the water supply is drawn only from the Illinois river basin there is 209.20; of the city of Philadelphia upon the assumption that the source of water supply is drawn from the Schuylkill river 330.63; and for Hamburg which draws its entire water supply from the Elbe river, 698.12. The lower figure by this method of comparison would indicate the best source of water supply, and if my method of reasoning is correct it would show that under the present conditions the Illinois river would be a safer source of water supply for the city of St. Louis than is the Schuylkill river for Philadelphia or the Elbe river for Hamburg. The water of the Elbe river at Hamburg is now and has been for 11 years past all filtered. Preparations are going forward to filter the water supply at Philadelphia from the Schuylkill as well as from the Delaware river.

And by the same process of reasoning it seems to me that the water supply of St. Louis should be filtered in order to remove any natural objections that exist to the sources from which its water is taken.

It would make no difference whatever either in the cost of construction or the cost of operation of a system of filters for the

city of St. Louis, whether the sewage from Chicago went through the canal or was entirely eliminated.

7564 Of the three rivers contributing their water to the supply of St. Louis, the Missouri river would create the largest percentage of cost in operating a filtration plant, owing to the silt and suspended matter.

7565 The amount of infection in the river—meaning by that, sewage infection, would not create an added cost to the operation of filters.

7566 Assuming that a filter plant should be established at St. Louis sufficient in size and suitable for the demands required, the fact that the Mississippi river at the Chain of Rocks varied from time to time, from slight infection to great infection, would not create any added cost to the operation of such a filter. The degree of sewage pollution or of infection of water coming to the filters would not be a factor either in determining their cost of construction or the cost of operation.

7567 The chemical and bacteriological investigations show in reference to the city of St. Louis that the Illinois river is the better source of supply, while the physical investigation that has been described shows that it is the least desirable source of supply. If we had no chemical and bacteriological data and were approaching the problem as a new proposition we would fix the center of population of the Illinois river water shed nearer the St. Louis intake than that of the Mississippi and Missouri water sheds. This mode of comparison of watersheds wholly ignores the volume of flow in each stream.

CROSS-EXAMINATION, by Mr. Jeffries:

7574 The Schuylkill river is much more polluted than the combined waters of the Illinois, Missouri and Mississippi. If the water from the Schuylkill and Delaware rivers should run down the stream with any added pollution or infecting material and should contain typhoid fever germs, if the water was of normal sewage pollution, I believe that all the typhoid fever germs would die out within eight days from the time they were

deposited in that water. I believe I would then recommend that water, but not for domestic purposes.

I would recommend it as being free from typhoid.

7575 Assuming that typhoid fever germs live in the water of the Schuylkill and Delaware eight days, the addition of a double quantity of water in that river would have the effect of slightly prolonging the life of the organisms.

7577 I think that is the true condition, that the pathogenic organisms, those that are not spore bearing, like anthrax for example, would have the shortest life in a very highly concentrated sewage.

7579 The fact of there being a smaller bacterial content in the water of the Illinois river at Ottawa and La Salle and at Wesley City, can probably be ascribed to the increased dilution of the water flowing in the channel of the river and partly perhaps to a greater rate of oxidation by reason of the added dissolved oxygen obtained from diluting the sewage with Lake Michigan water. I can not see clearly why this should cause an increase in the numbers at points below Pekin. In studying the table giving the bacterial content of the various waters discharged into the Illinois river and of the water of the Illinois river I thought that the increased bacterial content below Peoria was probably due to the sewage discharged at and below that point, and that it could not be connected with the increased flow of water in the Illinois river by reason of the draft on Lake Michigan through the drainage canal, because of the total numbers given in the table by far the larger percentage are the stronger and more hardy organisms of putrefaction and fermentation, organisms that would flourish only in polluted water, and some special cause of pollution must have occurred in the neighborhood of Pekin or Havana to bring about the considerable increase in numbers below that point, and this cause cannot be ascribed to the increased flow of water from Lake Michigan through the drainage canal.

7580 It is true that the tables introduced in evidence by me show that the percentage of reduction of bacteria in the Illinois river was greatest in former years from Morris to Ot-

tawa. Between La Salle and Henry the increase was slightly greater during 1900 than 1899. As a matter of fact, comparing the bacterial contents of the river at the various points from Havana down, the numbers were greater for the year 1900 than 1899, showing an increase in the content.

7582 Assuming that typhoid fever organisms entering the drainage canal at Chicago may be the cause, or are the cause of typhoid fever in St. Louis, then undoubtedly the temperature of the water flowing in the Illinois river, the variations in the rate of stream flow and other physical conditions in and along the river would have an influence on the resulting rates of typhoid in St. Louis. Assuming that the water in the Illinois river had a more sluggish current prior to the opening of the canal, I do not think it is necessarily true that the conditions existing prior to 1900 were more conducive to the destruction of pathogenic bacteria, assuming that they were contained in the water both prior and subsequent to that time.

7585 In view of the fact that the introduction of a considerable volume of relatively pure water from Lake Michigan with a corresponding considerable increase in the dissolved oxygen in the waters flowing in the river might contribute to a more rapid oxidation of the organic matter than if it depended entirely upon the processes formerly going on in the pools formed by the dams in the river or by the formation of sand bars, a situation that would happen in a river of a very sluggish current.

7586 Assuming that there is a city situated upon the Mississippi river immediately above the intake of the St. Louis waterworks, with a population of 13,000 people, in which typhoid fever is continually prevalent from one end of the year to the other, the extent of such fever being as much as ordinarily found in a city of that size, such city would be a menace and a danger to the people of the city of St. Louis, taking their water supply from the Mississippi river, and the measure of this danger would be the population of such city stated as 13,000, its

distance from St. Louis to the point of water intake and the rate of stream flow between the city and the intake.

7587 (The defendants, the State of Illinois and the Sanitary District of Chicago, rest their case.)

AT THE SOUTHERN HOTEL, ST. LOUIS, MO., May 23, 1904.

Continuation pursuant to agreement, being complainant's rebuttal evidence.

DR. EDWARD W. SAUNDERS, examined in chief by Mr. Jeffries:

Am a physician and have practiced in St. Louis 26 years.

7588 The Widal test is used for the discovery—or rather to ascertain whether or not the patient is afflicted with typhoid fever.

7589 This test has had no influence in my practice in making out death certificates to the health department of St. Louis. I consider that the Widal test is in general use by the profession in St. Louis.

7590 That test has been in use in St. Louis I should say about 6 or 7 years. The effect of that test in St. Louis, upon the profession, in signing and making out death certificates, I should say has been to take a number of cases from the typhoid list and add a number to it, because cases of nondescript fevers which before that time were assigned to the malarial list after that were assigned where they properly belonged, to the typhoid. On the other hand, there were quite a conglomeration of cases, patients dying in what the older writers called the status typhosus, or the typhoid state, which typhoid state had nothing to do with true typhoid fever, and these cases were taken out of the typhoid list.

I hardly think the Widal test or any other practice has resulted in taking from the malarial list and placing them in some other list besides typhoid. I can conceive of a case where a physician has treated a case for malaria and sees death approaching and makes the Widal test and finds it is not typhoid and that leads him to make a more careful examination and

finds the patient is dying of nephritis or something he had not found before. Yes, I can conceive of that case occurring.

7591 Q. I understand you to say then that since the Widal test has come in vogue, where patients believed by the attending physician to be afflicted with malaria and finding death approaching have applied the Widal test which has resulted in the death being recorded under some disease other than either malaria or typhoid? A. Yes, sir.

7592 I am of opinion that the effect upon the typhoid mortality of St. Louis since the use of the Widal test has been that a given number of cases occurring since the Widal test, will afford a much better mortality rate than the same number of cases occurring before the Widal test. Assuming all other conditions tending to recovery were the same, those in which the Widal test is used for an early diagnosis are found to show a better mortality rate.

7593 I am not sure about the time but I remember receiving a circular with reference to reporting typhoid fever, from the Board of Health, since the opening of the canal. That circular had no effect on me in reporting cases of typhoid to the health department. I was never influenced in my action in making such reports by receiving these circulars. I never heard the profession discuss the object of these circulars.

7594 I don't think any of the physicians in St. Louis have been in any way influenced by reason of receiving these circulars. I have no reason to think the opening of the canal would influence the physicians in making reports of death from typhoid fever in St. Louis. Assuming that a physician certifies that one of his patients died of congestive fever, I would not know what it meant. It would not necessarily mean typhoid fever.

7595 If a physician certified that one of his patients died of typho-malarial, I would understand that he died of typhoid complicated with malaria. If a case be reported as remittent fever, I would suspect that the patient died of typhoid, because indigenous remittent fevers are not fatal. If a re-

mittent fever patient died in infancy, then I would believe that that was the true cause of death. The same would be true with reference to intermittent fever. The same is true of malaria, but of simple continued fevers, I would say that they were all in the typhoid class. I would not even make the qualification that such would be the case, unless the patient were an infant, for the reason that a fever which continues any length of time, if it be malaria, is amenable to quinine. If not amenable to quinine,

I believe in the Osler dictum that any fever that continues

7596 a week and is not amenable to quinine and is not anything else, is typhoid. Simple continued fever I do not think could be anything else but typhoid. Infants and old people do not often die of typhoid fever. Those most likely to have typhoid fever are young adults. I have observed more or less typhoid in the winter and spring months within the last few years than formerly in St. Louis.

7597 I remember an epidemic in the fall of 1899 just before the opening of the canal. That was local and the cases were in the west end mostly, in the better quarters of the city.

CROSS-EXAMINATION, by Mr. Todd:

A patient may have typhoid fever and yet the doctor may fail to get the Widal reaction. I think the last report shows some 1600 physicians practicing in St. Louis.

7598 My acquaintanceship with those physicians would not exceed 20 per cent. That acquaintanceship does not extend to the bedsides of the patients they treat and their methods of diagnosis. Those that I have an intimate acquaintanceship with, as to their treatment of diseases are those I am called in consultation with. I am called in consultation with from fifty to one hundred different physicians every year.

7599 I should venture, as a guess, the nearest approximation I could make as to the number of cases of typhoid fever I treat in a year, on an average—that is, those that I treat and see in consultation—all together, would be from 30 to 50. I should say that I see anywhere from two to three or four or five deaths from typhoid in a year. I have no idea as to the number of

homeopathic physicians practicing in St. Louis. I do not know whether they employ the Widal test.

7600 I should say that all of the doctors in St. Louis, if they are in doubt, would be liable to appeal to the Widal test, in a case. If it should appear in the Board of Health statistics of St. Louis during the last ten years, that they have a group of deaths reported as remittent, intermittent, typho-malarial, congestive and simple continued fevers, and those deaths amount to something like 200, I think the number is a reflection upon the doctors of St. Louis in their diagnoses of disease of that character. That number of deaths, so characterized in the Board of Health report, reflects upon the diagnostic ability and carefulness of the doctors who make those reports. If the number of deaths appearing in the two columns were about the same, I should say that the majority of those cases in the remittent, etc. column, belong in the typhoid column. If such a condition obtained, as evidenced by the compilation of the Board of Health of the city, I should say that the doctors in St. Louis were not employing the Widal test generally. It is the tendency that these practitioners wedded to calomel and quinine are obstinate in accepting new treatment for diseases. If the deaths are about equal from typhoid and all these other diseases, that proves it.

7603 I would say perhaps the typhoid column is as inaccurate as the other column. If the typhoid column is as inaccurate as the other column, I would attribute the inaccuracy to failure in diagnosis. The words, "remittent, etc." are terms that have grown up but are not today employed by the advanced schools in medicine. Some of them are not recognized in the sense of being types of disease apart from the organism.

7605 It requires a great deal of skill among competent physicians to diagnosticate a case of malaria by the use of the microscope. The doctors in general practice in St. Louis are not possessed of that degree of skill necessary to make that diagnosis. That is true of typhoid fever. The fatality of typhoid fever depends largely upon the amount of germs taken into the

system. The Widal test was introduced in St. Louis I don't think to exceed six years ago. If it should appear that prior to six years ago there were more, or about an equal number of "remittent, etc." deaths in St. Louis, as compared with typhoid deaths, the death rate column would not fairly represent the typhoid condition in my opinion. I have had two cases under my observation where the malarial parasite had been found in the same patient with the typhoid bacilli. These cases are rare.

7608 In my practice, well I do not think that I have ever written a death certificate from any sort of malarial fever except in the very young when a convulsion carried off the patient in the onset, or in the aged where malaria carried off a very weak person. I do not believe I have otherwise made a single death certificate.

Assuming that a circular had been sent out from the Board of Health of St. Louis and that the public press was discussing the question of the effect of the drainage canal upon the water supply, and that the remittent, etc. fever column immediately decreased during the next three years and that the typhoid column increased—if those are all the facts upon which I am to base a judgment, I would say that such an increase would be manifest in the statistics of the Board of Health.

7612 DR. WASHINGTON E. FISCHEL, examined in chief by Mr. Jeffries:

Am a physician and reside in St. Louis. Have been practicing medicine here since 1874.

7613 I should say that the Widal test has been used in St. Louis about eight years. It is used to establish beyond a reasonable doubt the diagnosis of typhoid and to establish it as early as possible.

7614 Taking into consideration the value of the Widal test in making an early diagnosis and also that typhoid is a disease which, if properly treated in its earlier stages is less likely to become fatal, I should think that test would have the effect of lessening the mortality from typhoid. I think it is en-

tirely probable that there would be more deaths from typhoid when the Widal test was not employed. Persons are most likely to have typhoid fever between the ages of 18 and 45.

7615 I have observed more typhoid during the winter and spring months during the last few years, than formerly. I do not recall the members of the profession discussing a circular sent out by the Board of Health after the opening of the canal.

7616 Receiving those circulars has had no effect upon me personally. I believe that many cases of deaths from typhoid have not been reported as typhoid for the reason that if the physicians had reported these deaths as typhoid the Board of Health would have at once demanded an explanation of them why they had not been reported as typhoid before the death of the patient.

If a doctor certified that one of his patients died of congestive fever, I should not know what to understand by that term. I should not consider the true cause of death to necessarily be typhoid. It might be something else besides typhoid. When a death is reported as caused by remittent or intermittent fever, it is not necessarily typhoid fever. It may be any of the diseases which have a fever as a symptom, such as consumption. You may have pneumonia with remittent fever. I should say that in my judgment there is no such thing as typho-malarial. The effect of the opening of the canal has made me extremely careful of my diagnoses because, naturally, I felt there was great

7618 danger of the sewage of Chicago contaminating our water supply and I wanted to make it at least clear to myself whether in my experience that danger existed and therefore never reported a case as typhoid when the Widal test was not positive. I think the opening of the canal has made the profession more careful in reporting deaths from typhoid fever to the Board of Health.

At present I report no death as due to typhoid in which the Widal agglutination test has not been found positive. Previous to the issuing of the circular and the penalty which it conveyed to physicians neglecting to report typhoid cases, the cause

of death was frequently reported as typhoid when it might have been due to other diseases.

7619 CROSS-EXAMINATION, by Mr. Todd:

The converse is true—that many deaths from typhoid were reported as other diseases, which should have been reported as typhoid, prior to the opening of the canal. I know nothing definite about how to account for the number of deaths under the heading "Remittent, etc." I think many of these cases may have been tuberculosis.

7620 I think that the remittent, etc. deaths that appear in the Board of Health reports represent more typhoid than consumption. I think it is probably correct that the number of deaths as represented by typhoid would be a very small percentage of those prior to 1900 which would not be typhoid. I think the circular letter sent out by the Board of Health has made the physicians of this city more careful in reporting the typhoid cases.

7621 I think in regard to typhoid fever the chief reason for their having become more careful was the penalty attached by the Board of Health, in case physicians did not report typhoid fever. The number of deaths from typhoid fever may decrease or increase in a given community depending upon the skill of the physicians who are handling those cases, other things being equal.

7623 Many of those cases in the Board of Health reports of St. Louis under the heading "remittent, etc," I would attribute to faulty diagnosis. I do not recognize those diseases as distinct types of disease. I believe it is true that those are terms which have grown up in the profession and are employed by doctors who are not up in the medical profession. When I find a number of deaths aggregating 200, in a city the size of St. Louis, reported under the head of remittent, etc. fevers, that certainly leads me to the conclusion that there are a great num-

ber of doctors in St. Louis—the same as in any other city—who are not abreast of the profession.

7624 DR. LUDWIG BREMER, examined in chief by Mr. Jeffries:

Am a physician. Have been practicing for about 34 years.

7625 I am credited with the discovery of the blood test for diabetes. Have written and published a good many scientific medical articles. Am acquainted with the Widal test and have used it—not particularly in my own practice, but in order to verify its scientific significance, quite a number of times a number of years ago.

7627 Since 1900 I have gathered from the talk with the physicians and from hearing my patients talk about it, and the cases occurring in their families, that there has been an increase in the death rate from typhoid fever in St. Louis; I could not state positively that there has been an increase, but it is my impression that there has been an increase in typhoid fever in St. Louis.

From conversations with druggists, patients and physicians and others, I think it is the general concensus of opinion that there has been a gradual increase in the number of cases of deaths from typhoid fever since the opening of the canal.

7628 CROSS-EXAMINATION, by Mr. Todd:

I do not know how many cases of typhoid fever were in St. Louis for the period of four years prior to the opening of the canal nor how many cases of typhoid fever were in the city during the last four years, nor have I made a comparison of the statistics. Typhoid fever in St. Louis is not always distributed in all localities alike. It may appear in some localities more frequently and be absent in others. The greater number of the Widal tests are made at the Bacteriological Institute—a city institution. There are a number of young doctors who have been turned out of the medical schools in the last three or four years in St. Louis. It does not require a skilled physician to diagnose a typical case of malaria. Such fevers as are characterized by the names "remittent, etc." used to be recognized as distinct

types of disease. They are not now. I would say that no doubt a number of these cases under the head of "remittent, etc." are unrecognized or mistaken cases of typhoid. I do not know what percentage. The trend of the present state of medicine is that the best treatment of typhoid fever is good nursing and little medicine, so that the advantage of making a proper diagnosis of a patient is to prevent the treatment of that patient for some disease that requires medicine, which would be to the detriment of the patient if it were given.

RE-DIRECT EXAMINATION, by Mr. Jeffries:

The epidemic of 1899 in St. Louis, seemed to be confined to that part of the city where I live—out in the west end. The use of private filters has increased very materially, on the advice of physicians, during the last seven or eight years.

7633 I do not know whether they are still on the increase, but I know that a year or two ago I heard it from the physicians generally they recommended filtered water and boiling the filtered water afterwards.

The people of St. Louis have been educated to filter and boil the water and this education has been increased and extended considerably within the last four or five years. Every physician of common sense recommends the boiling and filtering today.

7635 RE-CROSS EXAMINATION, by Mr. Todd:

The epidemic of 1892 afforded a stimulus to me to advise the boiling of the Mississippi river water. I believe it did to any well-informed doctor. It was from 1896 to 1900 that the water supply of St. Louis was suggested as being unsafe for drinking purposes in its raw state, and since then it has been kept up.

7637 DR. ALBERT E. TAUSSIG, examined in chief by Mr. Jeffries:

Have lived in St. Louis all my life; am a physician.

7639 I had a couple of cases at the time of the typhoid epidemic in St. Louis in November and December, 1899. This epidemic I think was rather sharply localized in about the cen-

tral part of what is called the west end of town. Both boiling and filtering of water is used in the houses in St. Louis, a good deal more, in my opinion at present than in past years. These families whose regular physician I am, all boil their water. I insist on that and most of them filter their water. I think practically all physicians advocate that very strongly. These precautions are not always observed by the citizens, but one tries to have them observed as well as possible. My opinion is that private filters in the private houses in St. Louis have increased in the last four years. I base this impression simply upon the fact that the greater number of families about whom I know something have put in filters.

7641 Circulars that I might receive from the Board of Health admonishing me to report promptly all deaths from typhoid, etc. might make me a little more observant of my duties where otherwise if I had a case of typhoid fever, I might neglect to report it as such. The effect would be doubtless that I should report a greater number of cases of typhoid fever. I do not think it could possibly have any influence on the death certificates that I should write, for that depends on my own diagnosis.

CROSS-EXAMINATION, by Mr. Todd:

I think it always has been a wise precaution to boil the water, or at least since it seemed probable that typhoid was a water-borne disease.

7642 During ten years at least, it has been a wise precaution to boil and filter water in St. Louis, to prevent typhoid infection. The epidemic of 1892 caused a great many people to begin the systematic boiling of water, who had not done so before.

7644 Under the head of "remittent, etc." diseases reported to the Board of Health, I believe that some were typhoid, some consumption, some probably still other diseases. Assuming that "remittent, etc." fevers was not the proper cause of

death in such cases, such a diagnosis reflects upon the ability of the physicians sending in such causes of death.

7648 As to the words "remittent, etc." I think it is likely that in the mapority of causes in which these terms are used they are simply descriptive of the symptoms, but they may mean much more than merely typhoid and malaria. A great many diseases might, upon a superficial examination, produce the same sort of an impression.

Some of those terms, to my mind, cannot be called diagnosis at all.

7657 DR. CHAS. H. GOODMAN, examined in chief by Mr. Jeffries:

Am a physician. Have been practicing medicine in St. Louis about 35 years. I use the Widal test in my practice. The Widal test enables the physician to obtain an early diagnosis and therefore, early treatment may be given, which has enabled physicians perhaps to place the causes of death to typhoid that possibly they might not have done otherwise. It is also true that it would have enabled physicians to have ascribed deaths to some other cause than typhoid, and therefore, to have eliminated deaths as caused by typhoid, from the typhoid list. I believe that the use of the Widal test has enabled physicians to give patients such treatment in typhoid cases which otherwise would have resulted in malignant cases and therefore, the death rate would be reduced by means of the use of the Widal test, as the fatality has been somewhat reduced. The fact that letters and circulars were sent out by the Health Department made no difference with me, nor did the opening of the drainage canal have any effect upon me in making reports. So far as my acquaintance with the physicians in St. Louis goes, they generally recommend that the water be filtered or boiled. Unquestionably, domestic filters are in more general use now than six or seven years ago.

7663 So far as the mere clearing of the water is concerned, domestic filters are satisfactory but as to clearing it of the germs or rendering it any more safely drinkable, I have my

doubts. The epidemic of 1899 was localized in the west end of the city. It did not extend to any other portion of the city in general. It was in the better resident portion of the city. We have typhoid fever here more in the fall or early spring although the worst cases I have seen personally have been in the middle of winter. As a general proposition, it is at the change of seasons—from summer to fall and spring to summer.

7664 CROSS-EXAMINATION, by Mr. Todd:

7666 A young practitioner, a man who had a limited experience possibly could be mistaken in diagnosing typhoid fever. When I say that any ordinary physician can diagnose a death from typhoid fever, I mean only men of equal standing with myself. At times, it is a difficult matter for the very best doctors to diagnose a case of typhoid fever. I do not recognize remittent, typho-malarial, congestive and simple continued fevers, as distinct types of disease. These terms are characteristic of certain diseases rather than the disease itself. In

7668 the deaths reported to the Board of Health as "remittent, etc." those persons might have died of typhoid fever. They must have been confounding the terms, or they confounded the diagnosis of cases I should think. I do not know of any such fatality from malarial fever as would justify placing those deaths under the head of malarial fever. Considering that there are such a large number of deaths reported under the head of "remittent, etc." in the years 1891, 1892 and 1893, I believe the doctors at that time reported cases of typhoid deaths under "remittent, etc." deaths. (Statistics read to witness from 1894 to 1898, inclusive.)

7670 On the supposition that these figures were correct, I will say that the reports may have confounded diseases. Those that were reported as typho-malaria might have been typhoid, or typho-malaria, congestive, remittent or intermittent. These statistics cannot be accounted for in any other way than that typhoid fever has been wrongly diagnosed under those various headings. While the letter sent out by the Health Department in 1899 had no effect on me, I am not prepared to state that it

had no effect upon any of the doctors who practiced in St. Louis. I cannot account for the increase in the remittent, etc. column of the statistics of the Board of Health for four years previous to 1900, and the increase in the typhoid fever since the year 1900, in any way except that the fevers which have heretofore been diagnosed as remittent, etc. have been diagnosed as typhoid, and placed in the typhoid fever column, when prior to 1900 they were placed in the remittent, etc. column. If a letter was sent out by the Board of Health asking a report on typhoid fever, under penalty, I think the doctors would make reports accurately.

7676 I account for the large number of reported deaths for four years previous under the remittent, etc. column, and the small number since 1900, to mistaken diagnosis, that is, classifying those diseases which were probably typhoid, under typho-malarial.

7679 DR. HERBERT E. SMITH, examined in chief by Mr. Jeffries:

I reside at New Haven, Conn., and am Dean of the Yale Medical School, which is the medical department of the Yale university. (Gives educational qualifications.) Have been professor in chemistry, State chemist for Connecticut, and did work for the Connecticut State Board of Health in the investigation of rivers pollution in that State, and the examination of water supplies. For 14 years, have had immediate charge of all the chemical and bacteriological work which the board has done on the matter of rivers pollution and examination of sewage and sewage effluent and drinking water.

7680 I began the study of bacteriology in 1887. Am familiar in a general way with the method and results of chemistry and bacteriology as applied to water and sewage. (Witness gives list of epidemics which he has investigated.)

7683 About three years ago, I think it was, I was appointed as lecturer on the Interpretation of Water Analysis in the Sheffield Scientific School of Yale University, and have continued to hold that position and to give instruction to the class

in sanitary engineering in that branch. (Witness is shown tables presented in this case by Prof. Kinnicutt.)

7685 I would state that the figures represented in these tables do not furnish sufficient data to permit me to form a positive opinion as to the value, as a sanitary apparatus for the purification of the sewage of the drainage canal. The figures do show that there is a considerable solution of the suspended matter; that there is a considerable decomposition of the organic matter; that there is the development of a considerable amount of free ammonia.

These changes are such as are found taking place in sewage which is stored, by the agencies of the bacteria.

7686 The tables also show that there is a considerable reduction taking place in various ingredients in the sewage in passing through this canal. In so far there is a removal of the polluting material from the sewage, but in an important element in the discussion these tables are incompetent to form an opinion as to the destruction of the pathogenic organisms, particularly the typhoid fever, and there is no data with which I am acquainted which will give a true value to the extent to which bacteria may be destroyed or are destroyed in such an apparatus. The experiments which have been made tend to show that there is a reduction of the typhoid bacteria under such conditions, but how efficient such an apparatus is, it is impossible to state.

In my opinion the introduction of the large quantity of water discharged would tend to reduce the purification which would take place in an apparatus of this sort.

(Witness is shown tables 41 to 52 inclusive, introduced by Prof. Kinnicutt.)

7687 These results show the average composition of the samples of water at the times and places at which they were collected. The several samples show that in the upper portion of the water way there was a high chemical and bacterial pollution; that there was a gradual diminution in the amounts of the various chemical constituents in the progress down the river and that there were certain places where there was an increase in

these constituents; the figures for the samples taken at Grafton show there was in those samples a very considerable evidence of sewage contamination still remaining. There was some variation in this diagram, also in bacteria, the number at the Grafton station being somewhat higher than at the Kampsville station, for instance.

The tables fail to show the true conditions of the river at these several stations at all times because a sample taken from a running stream, from time to time, can not of course show the composition of the river at that place at other times, and further, there is no evidence in these tables that the samples taken at the time they were taken were proportional to the flow in the river, and obviously they would represent a different proportion of the constituents in the river at times of flood from what they would at all times of low water, the samples being of the same size.

MR. TODD: I move to strike out the answer for the reason given in the objection to the question, and for the additional reason that no witness has testified that the samples taken, as evidenced by the tables, express true conditions for the entire year, but only for conditions for the time covered, the period covered during the taking of the samples, and for the additional reasons given in my objection to the question itself.

(Witness is shown tables 67 to 74 inclusive, and states:)

7688 In my opinion, these tables do not show the condition of the water in the river at the several points at all times of the year, for the reason that the samples were taken occassionally and not continuously; that they did not as far as the tables show, take into consideration the flow at the time the samples were taken and that in general an average of this sort can not show the condition of the stream at other times than those at which the samples were taken. As to tables 1 to 12 inclusive, introduced by Prof. Kinnicutt, in my opinion, these tables fail to show the condition of the water in the river at all times and

seasons for similar reasons stated in my answer to your last question.

7689 In my examination of the individual results upon which these tables of average are based, I have noted many results which deviate widely from the average.

As an illustration, on table 101 in the Streams Examination, which relates to the analysis of the Illinois river at Grafton during 1899, I found that on November 8th, the samples showed a chlorine of 4 parts per million; on May 31st of 3.7 parts per million, while the average given in Professor Kinnicutt's table of results obtained at this point is 18.4 parts per million.

7690 I would say that on that particular table there were 17 samples, more than half, therefore, that were above the average in chlorine, and there were 16 that were below the average.

With regard to the free ammonia, I find that on December 6th there was present 1.12 parts per million, and on June 21st, .04 parts per million, while the average of all the determinations at that point gave 0.23. There were 12 samples above the average and 21 samples below the average.

In the same tables, the figures for suspended matter, or suspended residue referred to in another place as suspended solids, was, on May 31st, 873.8 parts per million, and on October 11th was 1 part per million, while the average of all the determinations is given as 82.4.

These indicate some of the ranges which I have noted, and similar discrepancies are found in the other tables.

MR. TODD: I move to strike out the answer for the same reasons heretofore given.

The general average does not show a true condition because the general average can only relate to the conditions at the times and places when and where the samples were taken.

In a stream of running water, which varies in volume, it is very important that the samples should be taken in such volume

as will indicate the relative flow at the time the samples are taken.

For another reason a sewage contaminated stream varies greatly from time to time in its content of impurity, depending largely upon the irregularities in the discharge of the sewage, at one time the sewage being of a certain character and at another time differing widely from it, either because of the sort of discharge of materials from factories or manufacturing establishments or something of that sort, or from the variations which are found in the flow of sewage in the matter from houses at or during different hours of the day. Moreover, there is a very marked difference in the flow of streams, due to the variable rainfall at different seasons and times. This has the effect not only of increasing the volume of the flow, diluting it at one time, the constituents over the conditions which prevail at another time, but the larger flow tends to bring down the stream accumulated materials and form movable deposits, both upon the watershed and in the stream itself. For these various reasons an average result can not show the condition of the stream at all times.

7691 In my opinion the tables of averages which are referred to as having been introduced by Prof. Kinnicutt do not form a competent basis in the present condition of sanitary science to permit a definite opinion as to the sanitary condition of the stream to which they relate. (Witness gives reasons, among which are, that the chemical analysis alone is not sufficient basis on which to decide whether a sewage polluted stream contains the dangerous elements of sewage and that the bacteriological analysis does not reveal in all cases the presence of those constituents of sewage which are dangerous, nor that both together can be absolutely relied upon to show the presence in the stream of those substances which may, and do come, from sewage and which are dangerous.) In answering questions relating to the analyses I have taken into consideration

the information obtained from the tables in the book known as Streams Examination.

7693 From my examination of the results given in the tables in the book, Streams Examination, and of the tables of averages based thereon, I would say that I am unable to state that they show that all injurious ingredients have been eliminated from the sewage.

7694 Taking into consideration the urban population upon the several water sheds tributary to the Illinois river, exclusive of that of the Chicago sanitary district, I will state it is my opinion that the results shown in the tables of averages based upon them, show that at the times when these samples were taken there was more evidence of sewage than I should expect in a river of this size and population.

In my opinion the tables referred to do show that there was at the times when the samples were taken more evidence of sewage contamination than I should expect to find from the urban population on the watersheds tributary to the Illinois river, exclusive of the Chicago sanitary district.

7696 In answering your question I have taken into consideration the assumptions and statements made and would state it as my opinion that the conditions assumed and stated to be present in the river prior to the opening of the drainage canal were such as would afford greater facilities for the removal of pathogenic organisms than those which exist since the opening of that canal.

And, further, I would state as my opinion that the data furnished by the tables in the book of Streams Examination, and the tables based thereon, do not furnish data for determining the extent to which these pathogenic organisms have been removed.

7697 In my opinion the data furnished in the tables show that there has been considerable removal of the polluting material introduced into the river from the sewage of Chicago, but

that they are not sufficient to determine that the purification from the dangerous elements in the sewage has been complete at all times and all seasons.

Basing my opinion upon the results of the chemical and bacteriological analysis which have been furnished, and the tables referred to, and upon other data within my knowledge bearing upon the subject I would state it as my opinion that the sewage is not purified from the harmful agents at the time it is discharged from the drainage canal.

7698 Assuming that the water passes from the city of Chicago to the Chain of Rocks within ten to twenty days, I am of the opinion that the water is less valuable for sanitary use than it was before the opening of the sanitary canal and that there is very much greater liability of infection by typhoid bacilli of persons drinking water from that point in the river.

7699 In my opinion, an increase in the flow of the Illinois river, by the addition of 250,000 cubic feet of water in the canal would very largely increase the liability of the infection of persons drinking a water supply consisting in whole or in part of water from the Illinois river.

7700 Replying to your question, I will state that there are factors in my knowledge which would lead me to believe that the Illinois river was infected by the sewage of Chicago, and that the mingling of this water with that of the Mississippi river and Missouri river is a serious menace to the health of persons living below the mouth of the Illinois river.

Assuming that there is no typhoid fever pollution of the waters upon the watershed of the Mississippi river and its tributaries above the intake other than that derived from the sanitary district of Chicago. I do believe that typhoid bacilli from the sewage of Chicago are liable to find their way into the water supply of St. Louis through the intake.

7701 I will state it as my opinion that I would believe that the introduction of the sewage from the city of Chicago has rendered the water of the Mississippi river less wholesome as a supply of drinking water.

7702 The best test which can be applied to decide whether a given water supply has been infected by sewage is to study the typhoid statistics of the community using the water.

7703 I would state it very positively as my opinion that typhoid bacilli living in the sediment of a polluted stream for the period of sixty days, would be able to produce typhoid fever if taken into the human system.

I will state it as my opinion that I believe when typhoid bacilli are deposited on the bottom of the Des Plaines or Illinois river, between Chicago and Peoria for a period of thirty or forty days they might retain their dangerous qualities as well as their pathogenicity, for I know of nothing which would make it certain that such an organism would meet with any material which would be certainly destructive to it under such conditions.

7704 I would state it as my opinion that sewage from the city of Chicago, passing through the course described in the question would be a menace and a danger to the inhabitants of Missouri and St. Louis using the water of the Mississippi river at the intake at the Chain of Rocks, for I know of nothing with which the infection contained in such sewage would meet which would be certainly destructive of it, and from my knowledge of conditions at Chicago such sewage must be very largely at times infected with typhoid bacilli.

7705 Taking into consideration all the knowledge which I have bearing upon your question, I will state it as my opinion that harmful elements of the sewage of Chicago have reached the intake of the St. Louis waterworks at the Chain of Rocks and have been the cause of typhoid fever among the persons using that water.

Taking into consideration all the data which you have enumerated in your question, I would state it as my opinion that the flow of the sewage of Chicago from the sanitary or drainage canal, through the Illinois river, has had a deleterious effect upon the health of the persons living in St. Louis and using the water drawn from the intake at the Chain of Rocks.

7708 Replying to the question I would say that I know of no experiments which are entirely satisfactory as proving typhoid bacilli are not able to survive the immersing in sewage for a period of three or four days; that there is nothing in the way of experimental knowledge to show that the typhoid bacilli may not survive in sewage for longer periods, and that taking these facts into consideration, and the further fact that typhoid bacilli might be deposited in the bottom of a stream at any point between the emptying of the drainage canal and the mouth of the Illinois river under conditions which would protect it from such deleterious influences as the sewage exerted upon the bacteria in the experiments which are referred to, especially in the question which you asked, it would be my opinion that typhoid bacilli might survive a very much longer period than three or four days and even be likely to do so if they were deposited upon the bottom of the Illinois river.

I have examined the evidence introduced by Profs. Zeit, Jordan and Russell, with reference to certain experiments conducted for the determination of the longevity of typhoid bacilli.

7709 In my opinion these experiments do not exemplify the true conditions, the conditions which exist in the water of the drainage canal with relation to the life of the typhoid bacilli discharged into that as a part of the sewage.

The opinion is based on several points: First, the introduction of typhoid bacilli in an artificial culture in such a quantity of sewage enclosed in a parchment sac which would protect it. This does not simulate the condition which would exist in the case of typhoid bacilli discharged into sewage and

coming from a patient suffering from typhoid fever in which case the organisms might readily be and frequently are enclosed in fecal masses.

Further, the condition of the bacilli in this sac is quite different from that which they would be under if they were free in the stream where they would be free to settle, deposited in the sediment they might then become protected from the influence of the sewage upon them.

In my opinion the condition of the water would frequently change at any one spot owing, as I have said previously in my testimony, to the changeable condition of the discharge which we find coming from the sewers in Chicago.

7710 I know of no previous experiments which were of such a character as to warrant the experimenters in making the assertion that the life of the typhoid germ, either in sewage, or sewage polluted water, is less than six days. As far as I know, the period of time set by Professors Jordan, Zeit and Russell is shorter than given by other authorities. Most experiments of this sort have demonstrated that sewage is in concentrated form detrimental to the life of the typhoid bacteria but the length of time which bacteria have lived in sewage of the different experiments have been so various that I do not recall a limitation expressed by any standard authorities on this subject.

Dr. Horrock's experiments showed that typhoid bacilli survive in unsterilized sewage a period of 14 days.

7712 Taking into consideration the data introduced in this case, and considering also the other facts which have come to my attention concerning the probable life of the typhoid bacilli after it has left the body of the patient, I would express it as my opinion that we would not be justified in concluding that the life of the typhoid bacilli would be limited to the period of three or four days under the conditions which are found to prevail in the drainage canal and in the Illinois river.

7713 In my opinion the experiments in those sacs deviate too far from the conditions which exist naturally and they are so much at varience with the ordinary experience which

persons have had who have had to deal with the tracing of epidemics of typhoid fever, that they seem to me to afford facts altogether too incomplete to risk an opinion of such wide and far reaching importance as the decision that would follow in a case of this sort. The decision is too grave to be based upon any such experiment in my opinion.

7714 Taking into consideration the various data to which you have called my attention, I would state that I have been able to find no evidence which to my mind is conclusive that the agencies at work in the stream are adequate to destroy the typhoid bacilli which undoubtedly are introduced into the sewage of Chicago and through it into the Illinois river, and therefore I believe that dangerous and infected pollution might reach the intake of the St. Louis waterworks.

7715 Considering all the data which I have been able to consider as bearing upon this problem, I believe that typhoid bacilli from the sewage of Chicago have reached the intake of the St. Louis waterworks.

7716 In my opinion the data available, especially those relating to the typhoid fever conditions upon the watershed of the Mississippi and Missouri rivers above the intake of the St. Louis waterworks, and the data concerning the occurrence of typhoid fever in the Chicago sanitary district, are sufficient to demonstrate that the increase in typhoid fever in St. Louis has been due in considerable part at least to infection from the Chicago sewage.

7718 I have examined the evidence introduced in this case as to the typhoid mortality in St. Louis for the last six or eight years. A comparison of the typhoid death rate in St. Louis for the years 1896 to 1899 inclusive, with that from 1900 to 1903 inclusive, is the best method of ascertaining the condition of the drinking water of St. Louis, with reference to this period. Of course, using in connection with that, the data concerning the upper watershed. In my opinion, there has been an increase in the typhoid death rate in St. Louis, based upon the mortality

per 100,000 population, or upon the percentage of typhoid deaths to the total mortality.

7719 I have examined the data given in the Health Commissioner's report and also those given in the compilation from the mortuary office referred to and have compared the data, and would state that it is my opinion, based upon these examinations and comparisons that there has been an increase in the typhoid death rate in St. Louis during the period covered by the four years, 1900 to 1903, inclusive.

7720 I would state that the comparisons which I have made indicate that the increase in typhoid since the canal was opened has been a very considerable one. The increase has been more noticeable during the winter and spring months than it has during the summer and autum months.

7721 I think that the use of the Widal test has probably not affected very materially the reports of deaths of typhoid fever. Its influence has been more marked in the matter of correct diagnosis of the milder cases of typhoid fever.

7723 I would state it is my opinion that the installation and operation of a filter plant at St. Louis would be more expensive by reason of the discharge of the sewage from Chicago into the Illinois river and that if the deleterious agents in this sewage were removed that the cost of the installation and the maintenance of a filter plant at St. Louis would be lessened.

CROSS-EXAMINATION, By Mr. Todd.

I have never made an examination of the whole course of a river as long as the Illinois river, but I have made frequent analyses, covering several years, of the Connecticut river, in that part which goes through the State of Connecticut. (Witness states what, in his judgment, is the proper method of taking samples, etc.)

7725 In the examination which I made of the Connecticut river, I did not pursue that method by any means. There was no attempt to make a thorough determination of the sanitary condition of that river at all times. I do not know of any analyst of waters who has pursued such a course in this country

or in Europe, according to the methods I have described. I should say that no one would be likely to recommend such a thing because the results obtained by those methods would not be comparable to the experience of course—in other words, the method is required to solve problems. The ideal method would be the one which I have just stated.

7726 In my investigation of the Connecticut river, the samples were taken only once a month. The samples of water in the Connecticut river were taken at four stations. That river in the State of Connecticut is about 75 miles. I haven't had any experience in the operation and management of what is known as septic tanks.

7729 From the evidence given in the tables by Prof. Kinnicutt, I should say that there was a very considerable reduction in the constituents of the sewage between the point where it enters the drainage canal until it leaves the canal at Lockport.

According to the tables, especially the table E, which is a comparison of the loss in certain ingredients in that tank as compared with the loss in certain other specified septic tanks, there is a loss which is to be accounted for by the bacteriological action which takes place and is responsible for the beneficial action of septic tanks.

That is what is commonly known as septic action.

7730 The effect of an increased speed in the current of the Illinois river would be to hasten the passage of the water from the upper reaches to the discharge, and also to lower the point where the most active oxidation effects take place, and also to carry down any matter which was suspended and which otherwise would tend to sink.

7733 In making up my opinion and giving my testimony, I do not recall that I have seen the tables made by Professors Teichmann, Ravold or Keiser. In its raw state, I would not recommend the water of the Missouri river for drinking water, to any community.

7735 If it were feasible to recommend an ideal water supply, under all considerations, I should recommend that the water of the Missouri river be treated more efficiently than by

the sedimentation tanks, but I should also have to consider that the statistics of the typhoid fever rate which, in my opinion, is on the whole the best test of the sanitary condition of the drinking water during the four years, 1896 to 1899, inclusive, would indicate that the water at that time was in a pretty satisfactory sanitary condition, and if it was not possible to have the ideal conditions, I would be willing to recommend under those conditions the continued careful use of the present sedimentation system.

7737 I would say that I do not consider the Missouri river water an absolutely safe water, and that there are very few absolutely safe waters, even waters which have had a certain amount of contamination and are filtered are not absolutely safe. Such things are not accomplished readily. One has to decide as to the reasonable safety of all conditions and this, I consider, has been shown during the years in question by the statistics which have been quoted.

7738 I would recommend the water as a reasonably safe water but personally knowing the dangers of typhoid infection and having in my family young persons of an age which is particularly susceptible to the infection of typhoid fever, I should hesitate to have my family use it, and would not do so under ordinary conditions, but I should have to recognize and did recognize, in giving the opinion that I could recommend the water as a reasonably safe water, that the average community in the United States do not as yet accept as high a standard for their requirement of drinking water as I should with my own knowledge for my own individual use.

7739 I would say the same as to the Illinois river for the period under consideration (prior to 1900.)

7741 Replying to your question I would state that I have already answered that the water supply which was used in St. Louis during the period in question gave such results according to the test of the typhoid fever death rate that in my

opinion, as I have stated, it was during that time a reasonably safe water and I understand that during that period a part of the Chicago sewage was discharged into the river. The removal of that would of course, not affect my opinion as already expressed, so that I would state explicitly that I would not recommend as already stated, the water in use at that time as an absolutely safe water but the results of the tests are, in my opinion, sufficient to justify one in recommending it as a reasonably safe water.

7742 As to whether I would recommend any river in this country as a safe drinking water and for domestic purposes, without filtering, I would say that assuming by "safe" you mean absolutely safe, that I suppose there is no river which flows over the surface which might not at some time become infected and that, therefore, under that assumption, I could not recommend them in this country. There are many mountain streams which have been used for long periods with no ill effects to the persons using them as far as typhoid fever is concerned. I can conceive of a water being absolutely safe, but it is so difficult to find a large quantity of water that is absolutely safe that I should not expect to be able to recommend any supply of water in a large community that would be absolutely safe.

7743 Under certain conditions there might be other methods of purification which could be substituted for filtration. I could not recommend the water from any river in this country that received the sewage from any city above it, as well as the sewage from the rural and urban population, as a safe water supply for a city, without filtration. Under certain conditions, the process of purification by subsidence might accomplish satisfactory results. I have never been called upon to pass judgment upon the quality of a river water for drinking and domestic purposes, when I recommended subsidence.

7744 I have never recommended for municipalities the use of river water without filtering.

The opinion that I gave that it would cost more to filter the water at St. Louis because of the addition of the water from

the Illinois river, was a general one, and not a specific one which would require the knowledge of an engineer. The largest filter plant in existence in this country is at Philadelphia. I do not know that at that plant the question of infection is not an element of cost, either in the building or in the operation of same and that the chief cost is in the removal of matters in suspension.

7748 I have not made any laboratory experiments upon the longevity of typhoid bacilli in sewage myself. The opinion I expressed was that the laboratory experiments were so different from the conditions naturally occurring in sewage polluted streams that in my opinion they were not adequate, therefore I do not credit them as being sufficient to form a judgment on that matter, and did not express an opinion. I do not know of any experiments that have been made by any bacteriologist in this country or Europe that simulates natural conditions as nearly as the experiments made by Professors Jordan, Zeit and Russell and which were as extensive in their scope as that experiment, upon the longevity of the typhoid bacilli. Unquestionably the technique of such experiments could be rendered somewhat more approaching natural conditions.

7750 It would have obviated one difficulty if the sacs had been allowed to float down the stream, properly protected so that they would not have been subjected in succession to a series of different character of water as they must have been when they were put stationary at one point. This is one thing that would suggest itself to me.

These experiments might have been tried in sacs of such size as to admit the accumulation of considerable quantities of sediment with a view of ascertaining whether they would have influenced the result. That would have more nearly simulated the conditions in the stream.

The experiments were very carefully worked out and unquestionably they were very well done, but the difficulty of sim-

ulating natural conditions are what appear to me to be of importance.

7751 Doctors confound typhoid fever with other diseases. It may happen that they may report deaths that should properly be typhoid under some other head.

7752 There is a marked discrepancy between the list given in the report of the commissioner and the data which were compiled by Prof. Sedgwick and Mr. Lochridge from the records of the mortuary office.

7755 RE-DIRECT EXAMINATION, by Mr. Jeffries:

7756 In my opinion the present state of bacteriology is not such as will permit an expert to fix with accuracy the longevity of the typhoid bacillus in a running stream under all conditions and at all possible times.

Further that it is not possible to state with accuracy the comparative resistance of the colon and typhoid bacilli in a running stream under all possible conditions and at all possible times, and further that it is my opinion the present state of bacteriology is such that it is not possible to conclude from bacteriological analysis that a sewage polluted stream might be so purified as to be used for drinking and other domestic purposes with absolute safety at all times and all seasons.

The effect of a flood upon the watershed of the Des Plaines and Illinois river, upon the sewage of Chicago going through the canal, would be, first, to dilute the sewage, and to hasten the period of passage of it through the river.

7757 The trend, as already stated, of bacteriology researches is to show that concentrated sewage has some deleterious effect upon the life of the typhoid bacilli, consequently the effect of diluting the sewage by floods in the upper Illinois river would be to introduce a condition which would tend to increase the longevity of the typhoid bacilli in the water, first by the dilution of the sewage itself and second by carrying the organisms quicker into the lower stretches of the river where there is more dilution from natural causes.

Taking into consideration the total area of the watershed of the Illinois, Missouri and Mississippi rivers respectively, and the urban population on the Illinois river, including Chicago and the urban population of the Missouri and Mississippi rivers respectively, and also taking into consideration the bacteriological and chemical data that have been introduced in evidence, and the table of results as to the longevity of typhoid bacilli as ascertained by Professors Jordan, Zeit and Russell, my opinion is that the water of the Illinois river would be most likely to contain the largest relative number of disease organisms such as are transmitted by sewage. In my opinion the waters of the

7758 Illinois river do contain relatively more disease germs, such as are transmitted by sewage, than the waters of the other rivers mentioned.

7759 In my opinion this does apply to the water at the mouth of the Illinois river as contrasted to the water at the mouth of the Missouri, in the Mississippi, in the immediate neighborhood at the points referred to.

It is my very positive opinion that it is desirable to preserve the rivers of our country as free from pollution by sewagic matter as possible, and especially as related to their use for drinking waters, and considering the question also of subsequent filtration.

I will state it as my opinion positively that of two waters originally alike in other respects that one which has the least sewage pollution should be chosen for the process of filtration for a public drinking water supply.

7761 JOHN W. ALVORD, examined in chief by Mr. Jeffries: Am a sanitary and hydraulic engineer and reside at Chicago. I have been in the practice of my profession about 24 years. (Gives educational qualifications.)

7762 In 1888 I was engaged in conducting the litigation in behalf of the State of Illinois with the Sanitary District, in the course of which the hydraulics of the upper portion of the Des Plaines river were thoroughly reviewed. I have studied in general the progress of the construction of the drainage chan-

nel and the related questions, and was engaged in working for the special commission which reported upon its completion.

I have observed the Illinois river at Morris, Ill., where I designed the system of sewers; at Ottawa, where I was engaged in water power litigation; at Marseilles, where I advised as to the enlargement of the water power, and have also observed the general characteristics of the river at Seneca, La Salle, Peru, Hennepin, Peoria, Pekin and Havana, at which latter two places I have designed sewerage systems.

I am also familiar with the Mississippi river from St. Louis to Alton, to some extent.

7763 I have tried to keep myself posted upon bacteriology in a general way ever since it has come into use among engineers. I also familiarized myself with the subject of chemistry as applied to my profession to a limited extent.

I was employed in 1902 by the special commission that investigated the extension of the water supply of the city of St. Louis, and my part of the work was to study the financial history of the present works, their physical cost and the cost of their operation. In the course of this work I became familiar with the characteristics of these works and have visited the Chain of Rocks station and sedimentation basins, also the old station at Bissel's Point, and have studied the physical features of the sedimentation plant.

I have made a special study to some extent of the typhoid condition on the watershed of the Mississippi river above St. Louis, and obtained data in regard to the typhoid deaths and populations of these watersheds, from the record of this case. I have prepared a diagram showing the relation of typhoid fever deaths in St. Louis with typhoid deaths on the watershed.

7764 This diagram is based upon the typhoid fever deaths upon the watersheds of the Mississippi, the Illinois and the Missouri rivers respectfully, as shown by a tabulated sheet of the evidence upon that subject, introduced in this case. This

diagram is reproduced on page 7766 as complainant's rebuttal chart No. 1.

7769 It has been the endeavor in this diagram to disclose the causes for the increase in typhoid deaths in St. Louis during the last few years. In order to intelligently determine such causes, the typhoid deaths along the different rivers have been separated from each other and platted separately so as to determine the source of the most marked pollution. It will be seen that the deaths from typhoid on the Illinois watershed, exclusive of the sanitary district of Chicago, are fairly uniform up to the year 1899, but show a rise in the year 1900, the year in which the drainage canal was opened. Otherwise they seem to be fairly uniform for the years preceding and following the commencement in the rise in the number of typhoid deaths in St. Louis.

The deaths on the Missouri river watershed appear also to be reasonably uniform for the period under consideration, and the typhoid deaths on the Mississippi river watershed, while fluctuating somewhat more than the first two described, are nevertheless generally uniform before and near the rise in the typhoid deaths in St. Louis.

In summing up the total typhoid deaths on the watershed above St. Louis, as given in the record, it would appear that while there is some fluctuation and a low period about the year 1896 that at no time since the rise in typhoid deaths in St. Louis they have materially exceeded a fair average rate and have in fact fallen off since the year 1900.

It will be observed, however, that the addition of the deaths from the sanitary district almost doubles the total typhoid deaths, influencing the pollution of the St. Louis water supply and that such addition is materially increased during the years 1901 and 1902, so that in 1902 the total typhoid deaths are nearly two and one-half times the deaths on the watershed above St. Louis, exclusive of the sanitary district of Chicago.

A local epidemic in St. Louis typhoid deaths in 1892 is clearly shown by the diagram and is attributable to the contam-

ination of the water supply at the old station at Bissell, by Ginras Creek, and neighboring sewers.

Upon the removal of the source of supply from Bissell's Point to the Chain of Rocks in the years 1894 to 1895 there is shown a marked improvement in the total number of deaths from typhoid for the latter year.

7770 I should consider, after a study of the data that in all human probability the rise in typhoid deaths in the city of St. Louis, in the last few years, has been caused by the added typhoid contamination from the sanitary district of Chicago.

7771 I have for some years past considered the life of the typhoid bacilli would be from 60 to 90 days under favorable environments, and while large masses of such bacilli might be removed from any given source of supply in a comparatively short time under unfavorable environments, it would not be safe to assume that a water once thus polluted would be safe to recommend for public use, under the time given, unless the contamination were eliminated by a carefully designed and properly operated system of purification.

(Refers to experiments made by Mr. Mills and Dr. Horrocks.)

7772 The sewerage system of Chicago has very flat gradients and requires frequent artificial flushing. It has been the history of heavy rainfalls in that city that the entire content of the sewers are at such times disgorged into the river bringing into it a mass of pollution which has been accumulating for months together. Before the opening of the drainage channel such periods were extremely dangerous to the water supply of the city, as was shown in the increase in typhoid deaths following the period of such contamination. Such heavy flushings of rainfall occur ordinarily in the early spring or after the breaking up of the winter and at times when the temperature is most favorable to the longevity of the typhoid germ and greatly increases for the time being the rate of pollution in the drainage canal and Des Plaines and Illinois rivers.

In my opinion the action of such a flushing of the Chicago sewer system into the Chicago river with its present large proportion of pure water and low temperature furnishes con-
7773 ditions which parallel or indeed form more favorable conditions to the longevity of pathogenic bacteria than those under which the experimental work above noted were taken. The discharge of this various amount of pollution at times of flood waters appears also to furnish the necessary velocity for rapid conveyance through the drainage canal down the Des Plaines and Illinois rivers to the intake of the St. Louis water supply; the increment of tributary streams also increases the dilution and decreases the chance for toxic destruction of the total number of typhoid germs present. Such conditions are prevalent in greater or less degree during many times of each spring.

In the case of heavy rainfall on the watershed of the Chicago river, it is often necessary in order to prevent outflow into Lake Michigan through the main river, to lower the Bear Trap dam at Lockport so as to produce greater velocity at all stations down the channel at such times. This undoubtedly aids in the rapidity with which pollution is conveyed away from Chicago down the channel of the Des Plaines and Illinois rivers.

7774 Below the outlet of the drainage canal at Lockport, the Des Plaines river flows very rapidly to a pool formed by what is known as dam No. 1 at Joliet. This descent over ordinary and normal flow produces rapid velocity and a slight rise, but rainfall will develop velocity in the channel of from 40 to 60 miles per day. Below dam number one and at Joliet, the flow again becomes very rapid at times of moderate rises. This flow is slightly checked through Lake Joliet, but there is a further rapidity incurred on its outlet all the way down to the mouth of the Kankakee river. Below this point, the Marseilles dam slightly checks the current. Another rapid flow takes place below the Marseilles dam as far down as Peru, where the influence of the Henry dam is felt. In the time of spring rises the velocity in these reaches is very materially increased, running, as I have said, up to as high as forty to sixty miles a day. The

effect of the introduction of 250,000 cubic feet of water per minute through the Chicago drainage canal is to materially increase the current of the Des Plaines and Illinois river and to carry dangerous pollution to greater distances and with more rapidity. I fail to see the pertinency of Mr. Randolph's conclusion that a correction should be made of the maximum travel of the floats used to determine the velocity or length of time required for the travel of water from the canal to the Chain of Rocks.

7776 The use of the .8 correction, in the manner described in Mr. Randolph's testimony is a very rough approximation, used by hydraulic engineers when surface floats are run in the most rapid part of the channel of a river to determine the average flow for the whole cross-section of the channel in order to get at the quantity passing a given point per second. In the case under consideration, we are not endeavoring to determine the quantity of water passing any given cross-section per second, but the problem presented is what length of time will any given pollution, flowing in mid-channel, pass over the necessary distance from the Chicago river to the Chain of Rocks. This only requires, in my opinion, a determination of the mean velocity of the bore or central section of the stream.

I should not consider the floats described by Mr. Randolph and Mr. Crane, as surface floats.

As described in the testimony they appear to be partially submerged and I believe they give the mean velocity of the central portion of the stream with a fair degree of accuracy.

I should judge that fifteen days actual time would fairly represent the ability of the water of the Illinois and Des Plaines rivers to carry pollution to the Chain of Rocks at the stage when the experiments were made.

(Witness compares experiments made by Prof. Van Ornum and those made by Mr. Randolph.)

7779 Not having been able to ascertain the specific stage at the time of Mr. Randolph's experiments, I should be unable to state positively that his experiment was made at the mini-

mum stage of the river, but speaking generally, it is my impression that it was, and represents the average of the minimum velocity in the ordinary dry seasons of the year between the Chicago river and the Chain of Rocks.

7780 I have examined the chart referred to by Mr. Hering, which represents an attempt to derive the possible amount of contamination in the water at the Chain of Rocks, from the sanitary district of Chicago, by assuming that the original pollution is proportional to the population and that the longevity of a typhoid bacillus is, as found by the experiments of Hiram F. Mills in the paper referred to. The chart also makes the same deductions for the Mississippi and Missouri rivers and gives the rate of fall of the three watersheds. In the case of the Illinois river the length of time of flow from the Chicago river to the Chain of Rocks is taken at 18½ days, as stated by Mr. Randolph from his experiments, after adding to the original experiments an additional time for the correction to the mean velocity. It would seem to me in the first place that Mr. Hering has not given due weight to the relative effectiveness of different populations in the production of typhoid pollution. The sanitary district of Chicago has been afflicted for years with an abnormal number of typhoid deaths. Other cities on the Illinois watershed, deriving their water supply from artesian wells, have extremely low death rates from the same cause. It would appear, therefore, to me, that to make the diagram more exact some method should be introduced by which the

7781 disparity in typhoid data could be allowed for in its effect upon the St. Louis water supply.

Again, I should judge that the diagram as compiled under Mr. Hering's direction gives the time of travel of the pollution vehicle at low stages of the river and therefore does not fairly indicate the greater danger of pollution to the St. Louis supply at medium or high stages of the river. It would seem that the diagram should be so constructed that these modifications might be clearly apparent.

I have prepared a diagram which, according to the methods suggested by Mr. Hering, based upon the experiments of Mr. Hiram F. Mills, which would also include the two modifications just described by me.

This chart is marked Complainant's Rebuttal Chart No. 2, and is reproduced on page 7782.

7785 Assuming active typhoid contamination is proportional to the population, and assuming diminution in the number of typhoid germs day by day to be as shown in the experiments of Mr. Hiram F. Mills, the modifications which I have introduced in the diagram would considerably increase the amount of typhoid pollution entering the intake at St. Louis.

I find that whereas Mr. Hering's diagram shows that the typhoid pollution entering the intake at the Chain of Rocks is equivalent at the end of a low river flow of 18½ days to an

7786 infection from a tributary population immediately above the intake of a city of 13,000 people, the conclusions of the diagram would seem to indicate that the normal flow of fifteen days would be equivalent to an infection from a tributary population with a death rate of 20 per 100,000 living of a city located immediately above the intake, with a population of about 90,000 people, while on the basis of ordinary spring floods, such as were gauged by Professor Van Ornum the infection arising at the Chain of Rocks would be equivalent to the population of a city of 415,000 population, situated immediately above the intake tower, and with a typhoid death rate of 20 per 100,000.

With a maximum flood such as occurs only once in every several years, it would appear that the comparative pollution reaching the intake of the St. Louis waterworks would be equivalent to a population of 960,000 with a typhoid fever death rate of 20 per 100,000 living, this latter assumption being based upon the movement of the pollution vehicle from the Chicago river to the Chain of Rocks in eight days.

7787 I believe the investigations made by Mr. Hiram F. Mills, the results of which were used by Mr. Hering in his chart, might be termed incomplete investigation, that is to say, they

are valuable, but neither sufficiently comprehensive nor numerous. I have given particular attention to the development of septic tanks and have designed some ten or fifteen plants

7788 for municipalities in which a septic tank has been employed on my recommendations. Of these plants eight septic tanks have been constructed under my immediate supervision for different municipalities and have been in operation for periods ranging from one to four years. Two of these plants have been under my immediate supervision ever since construction and I have watched the operation of others.

Flowing sewage does not ordinarily undergo the process of septic action. Diluted sewage flowing in open channels would not simulate septic tank conditions.

7789 In the Chicago drainage canal we have a large volume of diluted sewage flowing at the rate of one to three feet per second, giving ample opportunity for renewing its dissolved oxygen. And we have this action further increased by the opportunity of the wind to stir the surface of the stream and still further oxygenate it.

We have also an opportunity for exposure to low temperatures, light, etc., which are detrimtal to the septic action. Septic action to any considerable extent does not take place in the sewage of Chicago during its passage through the drainage canal. My opinion is that the chemical data introduced by the defendants with reference to the character of the contents of the Chicago drainage canal do not indicate any septic action has taken place. The amount of improvement in the sewage in its travel of the drainage canal found by Professor Kinnicutt in his testimony in this case would seem to me to be largely due to aerobic action. Possibly there is anaerobic action to a very limited extent, but not enough in my opinion to influence the results perceptibly. The extensive dilution of the sewage of

Chicago by the richly oxygenated water of Lake Michigan is distinctly opposed to the inception of septic action.

7790 I was familiar with the south branch of the Chicago river prior to the opening of the canal. It presented all the characteristics of septic action to a marked degree. I believe that typhoid germs could survive materially longer un-

7791 der the present conditions than was the case formerly in the Illinois and Michigan canal and the South Branch of the Chicago river. Taking into consideration all the facts testified to, the presence of sewage from the sanitary district of Chicago, in the waters of the Mississippi, at the Chain of Rocks, makes it more costly to provide suitable water for domestic purposes for the citizens of St. Louis. The design and construction of a purification plant dealing with a seriously polluted water, especially of one of known high typhoid pollution, should be more complete and delicately adjusted to its work than when dealing only with water of rare infection and presenting less dangerous difficulties, such as turbidity and color.

7792 This added protection should take the form either of double filtration or have complete sedimentation in more than one stage followed by most careful filtration. (Witness states cases that he knows of where double filtration is being resorted to.) Such methods would greatly increase the cost of filtration both in construction and operation. Single sand filtration as practiced in the United States is not always a protection from the danger of typhoid infection.

7793 Sand filtration of either type is practically able to remove pathogenic bacteria from domestic water supply, but we find that in practice filtration works are a most delicate mechanism, which have to be very carefully operated in order to produce at all times and under all conditions the results anticipated by their designers. In cases where the danger of infection hovers over the filtration plant year in and year out it is obvious that the slightest relaxation may result in the most serious consequences.

There have come under my observation, typhoid epidemics in water supplies protected by filtration in the following places:

Rock Island, Illinois,
Ashland, Wisconsin,
Berlin, Germany,
Lawrence, Massachusetts,
Lake Forest, Illinois,
Butler, Pennsylvania,
Waterloo, Iowa,
Beaver Falls, Pensylvania, and
Augusta, Maine.

7795 I am of the opinion that it is entirely practicable to retain the drainage channel so that it can be still employed for keeping the Chicago river in condition and yet avoid pouring unpurified sewage into and through the canal and into the Des Plaines and Illinois rivers, and I would suggest as the proper remedy the construction of suitable intercepting sewers along the Chicago river and its branches, by means of which the sewage flow of the city may be kept out of the Chicago river and lead along its banks to the upper end of the drainage channel beyond Bridgeport and then raised by a suitable pumping station preferably operated with water power derived from the drainage canal to and into a suitable purification plant constructed in accordance with the latest bacteriological principles and effectually remove from such sewage all or practically all of its organic wastes and pathogenic bacteria and emptying the effluent from such sewage plant into the drainage channel near Bridgeport to be conveyed through the same and through the Des Plaines and the Illinois rivers in a harmless and purified state.

I have considered the expense in a general way and am of the opinion that such intercepting sewers and purification

plant could be constructed at an expense no greater than that necessary to widen the South Branch of the Chicago river
7796 in order to increase its flow of dilution water to the requirements of dilution.

And I am further of the opinion that the operating expense of such a plant would be no greater than the operating expense of the present system of pumping sewage and the necessary dilution water through the same for the northerly and southerly portions of the sanitary district and the dilution water for the proposed additions to such sanitary district.

CROSS-EXAMINATION, By Mr. Todd.

I would estimate the cost to be between twelve and fifteen millions of dollars. That contemplates the purification of the entire sewage of the sanitary district. (Witness is cross-examined as to method of putting such a plan in operation.)

7801 At the time Mr. Hering made his preliminary report, when the question of sewage disposal for Chicago was under consideration, the question of bacteriology was not then generally recognized as a science. The purification of sewage was then known and extensively practiced, but the systems which I now have in mind were not developed, and speaking generally, the systems then in use, while efficient, were ex-
7802 pensive. I have conducted no experiments upon the longevity of the typhoid germ.

7803 As to typhoid fever in St. Louis, I have not attempted to account for the rise evidenced on the chart, which I introduced in evidence, from 1899 to 1900. There is a slight fall for the years 1900, 1901 and 1902 in typhoid along the Illinois river, exclusive of Chicago. I have not attempted to account for it. There is a rise in the typhoid rate as evidenced by the chart upon the Mississippi river from 1899 to 1901. I have not attempted to account for that.

7805 An increase in typhoid fever in St. Charles might possibly be expressed in the typhoid conditions in St. Louis.

7807 I should be inclined to think from my diagram that the typhoid deaths in St. Charles might have influenced the normal typhoid deaths in St. Louis prior to 1900 to some unknown percentage. I should be disinclined to think that since 1900 the typhoid in St. Charles could have been responsible for so marked a change in the number of deaths in St. Louis from typhoid.

Q. Do you employ the theory of probabilities in drawing your conclusions that the typhoid increase in St. Louis is due to Chicago?

A. Whenever we deal with a problem of the magnitude of this problem and its complications, we are obliged as one of the contributing data to proceed on such theory.

I do not regard the water of the Missouri river in its raw state, as a safe drinking water. As treated by settling basins, I should say that it has only probably been greatly improved in its general character. It may be safely assumed that the water of the Missouri river has been deteriorating, as a safe drinking water for the last 25 years, and each year, more so, and the same is probably true of all our western rivers.

7809 I do not regard the Mississippi river water above Grafton as a safe drinking water. I do not regard the water of the Illinois, Mississippi and Missouri, eliminating the sanitary district of Chicago, treated as it is in the settling basins at St. Louis, entirely safe as a drinking water to be used by the city of St. Louis. If I were selected as a sanitary engineer, I should not like to recommend it. I do not know the stages of the river at the time Mr. Randolph made his float experiments, but I should think that they were the average low waters of mid-summer—that is an intelligent guess. Figuring out the average time between Chicago and St. Louis, I came to the con-

7810 clusion that at most stages of the river uninfluenced by floods of any kind, the time of passage of the pollution vehicle would be in the neighborhood of the float experiments,

as determined by Mr. Randolph or thereabouts, but not reduced to mean velocity, and that in times of slight or medium rises, the time of passage of the pollution vehicle would be apparently in accordance with the experiment of Professor Van Ornum, and that in time of very great floods, such as occurred in 1902, and I believe in 1888, and at one or two other times in my recollection, the time of passage might be reduced to eight days or less.

7811 The effect of the corrections that I have made to the chart of Mr. Hering, would be to place a city of 960,000 population, instead of 13,000 above the Chain of Rocks.

7815 If the sanitary district of Chicago should be eliminated, I should still recommend a filtration system for the water of St. Louis.

7819 RE-DIRECT EXAMINATION, by Mr. Jeffries:

As the infection material is increased in a running stream that is being filtered, it is recognized by all sanitary engineers that the construction must be more perfect, of a higher grade, that the equipment, maintenance and character of the employes must be more efficient.

7821 E. E. LOCHRIDGE, examined in chief by Mr. Jeffries: I live in Boston, Mass. Am bacteriologist and chemist. Have studied and examined into water supplies, etc.

7823 I have examined the tables of typhoid fever statistics for St. Louis, introduced by witnesses and now formally a part of the record of the defendants in this case, and especially introduced by Dr. Baker on October 24, 1903. The number of typhoid deaths given on that table for the years 1896 to 1902 differ only slightly from the results obtained by compiling the deaths attributable to typhoid fever in the record books of the mortuary office. I have made a special study of the tables for typhoid fever and other fevers in the office of the Board of Health of St. Louis. I do not believe that a comparison of the typhoid fever deaths prior to 1896 with those subsequent to 1896 is either practicable or feasible, for the reason that prior to 1896 the intake was so located as to expose the water supply to infection, and during 1894 and 1895, the intake was removed to

a point farther up the Mississippi river, at the Chain of Rocks.

7824 In order to show the great change in the typhoid fever mortality of the city of St. Louis, at the time the intake was moved, I have prepared a diagram which serves to illustrate this point, as well as certain other points to which I have occasion to refer hereafter.

Diagram reproduced as complainant's rebuttal chart No. 3, on page 7825.

7826 This chart represents the per cent of deaths from typhoid fever to the total mortality for the city as taken from the printed health records of the health department.

It will be noted that the death rate was uniformly high up to the time of the change of the intake from Bissell's Point to the Chain of Rocks. Following this change there is a period of five years in which the mortality is much lower. In 1900 there is a considerable increase and a step like increase through the subsequent years.

(Motion to strike chart from the record.) I have examined the mortuary records and have made tables showing the number of deaths from typhoid fever, remittent fever, intermittent fever, typho-malarial fever, congestive fever and simple continued fever in each month of the year from 1896 to 1903 inclusive. Said charts being numbered 4 to 9 inclusive, and are reproduced on pages 7828 to 7833, inclusive.

7835 I find six deaths marked continued or continuing fever, but none marked simple continued fever in the years 1896 to 1903, inclusive.

I have made a table of the deaths which I found recorded in the records in the mortuary office in the city of St. Louis, from malarial fever, for the years from 1896 to 1903, by months, which is reproduced on page 7835.

7837 Adding together the deaths which I found in the study of the records at the mortuary office from remittent, intermittent, typho-malaria, congestive and continued fevers, I find that for the years 1896 to 1899, inclusiwe, there were re-

spectively 129, 106, 85 and 86 deaths, and that if the number of deaths which I found in the records in the mortuary office from malaria are added to these, there are in these years respectively 156, 140, 108 and 121 deaths, while Professor Jordan gave for the corresponding years 177, 172, 134 and 148, or the number of deaths which I find recorded on the books in the mortuary office from these causes is a little lower in each year than the list taken by Professor Jordan from the printed health report.

In the four years from 1900 to 1903, inclusive, adding together the deaths which I found in the books in the mortuary office in the city of St. Louis from intermittent, remittent,
7838 typho-malaria, congestive and continued fevers, I find for these years 77, 62, 76 and 73 deaths. Adding to these the deaths which I find of malarial fever for these years, there were 137, 90, 114 and 126 deaths, or a little higher in each year than those given by Professor Jordan.

Considering the fact that the malarial fevers were in all probability recorded in this list as they do not occur under any other caption, so far as could be discovered in the printed health reports, I find that Professor Jordan has in his list 21 more deaths in 1896, 32 more in 1897, 26 more in 1898, and 27 more in 1899, 25 less in 1900, 10 less in 1901, 12 less in 1902, and 35 less in 1903, than I found in my study of the records in the mortuary office in St. Louis.

I have made other tables showing deaths from bilious fever, enteric fever and deaths in which typhoid was assigned as the cause, but not the principal cause, and typhoid-pneumonia deaths. These charts are numbered 11 to 13 inclusive, and are reproduced on pages 7840 to 7843 inclusive.

7844 I have tabulated the typhoid fever deaths in the city of St. Louis, according to the residence address at which the patient died, for the years mentioned. This chart is repro-

duced as Nos. 15 to 22 inclusive, on pages 7845 to 7852, inclusive.

7855 These charts show that since the year 1900, the distribution throughout the seven sanitary districts has been very uniform when we consider the deaths occurring in hospitals, but referred back to their residence district. There is no district in which there was an unusual number of deaths when compared with other districts since 1900. The distribution of the typhoid deaths in the various districts has been quite uniform since 1900, such as might be expected if the cause for the typhoid were one which would be equally applicable to all of the citizens of the city in the way that pollution by water is applicable. I have prepared similar charts showing the deaths from malarial fever in St. Louis, by districts, numbered 23 to 30 inclusive, and they are reproduced on pages 7856 to 7863, inclusive.

7864 The tables indicate the distribution during the year in the city and the increase in malaria from year to year between the years 1896 and 1903, which show that the distribution in these districts is not as uniform in the city as is the case of deaths from typhoid fever. I have prepared charts showing the deaths from typho-malaria during the same years, numbered 31 to 38 inclusive, and reproduced on pages 7865 to 7872, inclusive.

7873 These tables show the total number of typho-malaria deaths in each of the seven sanitary districts for each month for the eight years mentioned, each year being on a separate chart. The distribution is here, as in the case of the malaria, less uniform than the distribution of the typhoid fever deaths.

I have prepared charts of deaths from typhoid fever in St. Louis for the years 1896 to 1903, inclusive, in which the deaths from this cause are tabulated according to age at time of death and by the month of the year. These charts are numbered 39 to

46 inclusive and are reproduced on pages 7874 to 7881 inclusive.

7882 From a study of these charts which give the data in regard to the age and time of the deaths from typhoid fever in St. Louis during these eight years, it will be seen that a large proportion of the deaths occurred between the ages of eleven and fifty, and the ages of six to sixty will include practically all of them.

The number of children dying of typhoid, of those under six months or from six months to one year is the same in the first four years as in the last. The increase for any given age can be noted by comparing the charts of the four years, 1896 to 1899, inclusive, with the charts of the four years, 1900 to 1903, inclusive.

These charts not only show the increase in the number, but also the increase under each of the ages, and also by the season of the year. This may be noted by a comparison of the number of dots for any given month and for any given age.

7883 During the early years represented by these charts the number during the months of January to May, and the month of December is quite low, while since the year 1900 there has been a very marked increase of the number of deaths for this six-month period, much more in proportion than during the other six months.

I have prepared similar charts of the deaths in St. Louis from remittent fever for the years 1896 to 1903 inclusive, in which the deaths from this cause are tabulated according to ages at time of death and by months of the year. These charts are numbered 47 to 54 inclusive, and reproduced on pages 7884 to 7891, inclusive.

7892 In all of these tables the variations in the number of deaths from this cause will thus be seen to be in the column of children under three or people above 61 years of age, the numbers during the ages ordinarily considered as typhoid ages and indicated on the typhoid charts, both before the opening

and since the opening of the canal, as typhoid ages remains about constant.

Have prepared similar charts of the deaths from intermittent fever, which charts are numbered 55 to 62 inclusive and reproduced on pages 7894 to 7901, inclusive.

7902 The total number does not vary materially before and since the opening of the canal with the exception of the year 1899, in which there are nearly twice the number recorded for the other years.

However, in the year 1899, it will be found that there are five deaths of children under six months of age from this disease and five more between the age of six months and one year.

With this exception the number is practically the same during each of the years covered by these charts.

There were 17 deaths from intermittent fever in St. Louis in the year 1899, as shown by this chart, of persons either of or below the age of three years and of or above the age of 61. This number subtracted from the total of 25 leaves 8 of the ages when typhoid fever is most prevalent.

7903 There was not a single death from intermittent fever during the year 1899 of a patient between the ages of 11 and 30 years.

There are a considerable number of deaths during the summer months, as for example, in 1897 all of the deaths were between April and October inclusive.

I have prepared similar charts showing deaths from typho-malarial in St. Louis, numbered 63 to 70 inclusive, and reproduced on pages 7904 to 7911 inclusive. I have prepared similar charts showing deaths from malarial fever, numbered 71 to 78 inclusive, and reproduced on pages 7913 to 7920 inclusive.

7921 I have prepared chart showing deaths in each year by months for the four years subsequent to the opening of the drainage canal from congestive fever, numbered 79, this is reproduced on page 7922, also chart numbered 80, showing deaths

like chart showing summer conditions, numbered 85, which is reproduced on page 7934.

7935 I have also prepared a chart entitled, "Comparisons of Typhoid Deaths," numbered 86, being a comparison of typhoid deaths in St. Louis for the winter and summer months, prior to and since the opening of the canal. Said chart being reproduced on page 7936.

7937 This chart is intended to show the relative increase in typhoid fever in the winter and summer months as between the period prior to the opening of the canal and the period subsequent thereto.

7942 Deaths from typhoid fever in the year 1896 will be seen to lie quite well between the ages of 6 and 60, while 22, or considerably over fifty per cent of the remittent fever deaths for this same year are either younger or older than the ages mentioned, or in other words, are either infants or old people.

In the year 1897 there were 11 less deaths from remittent fever than there were from this same cause in 1896, but that loss might be considered as entirely among the very

7943 young children, and it can be seen by referring to the typhoid deaths for 1897 that not one of these has been added to the death rate from typhoid fever, or in other words there could have been no transfer to typhoid fever due to better diagnosis. If the change in the annual number of remittent fever deaths be due to such better diagnosis, these deaths have been referred to some other disease than typhoid fever. A study of the tables through all the following years from remittent fever will show this same variation, the variation being in the number dying under the age of six years, the number of deaths remaining practically the same during the ages in which the mass of the typhoid fever deaths occur.

In the year 1896 there were 12 deaths from intermittent fever and in the year 1897 there were 12, but these may be seen to have been in entirely different ages, the same variation in the number of deaths in children under the age of 1, particularly, and in some cases under the age of 6, being quite

from congestive fever for four years subsequent to the opening of the canal, and this chart is reproduced on page 7923.

7924 I have prepared two charts of bilious fever deaths, one covering the period from 1896 to 1899 inclusive, numbered 81, reproduced on page 7925, and another covering the period from 1900 to 1903 inclusive, numbered 82, reproduced on page 7926. Chart 83, reproduced on page 7928, shows deaths from enteric fever from 1896 to 1903, inclusive.

7929 During the eight years between 1896 and 1903 inclusive, there were six deaths marked continued or continuing fever, two of these occurring in the four years prior to the opening of the canal and four occurring in the four years subsequent to its opening. The typhoid fever charts show the largest number of deaths occur between the ages of 11 and 50, and on either side of these ages, that is, under 6, and over 50, there are few deaths from typhoid.

7930 In the earlier years, notably the first four years, 1896 to 1899, inclusive, the much larger proportion of deaths occurred between the months of July and November inclusive. During the years 1901, 1902 and 1903, it will be seen that there are much larger numbers than the proportional increase in the months just referred to, during the months from January to June, and in the month of December, so that during the latter years the typhoid fever deaths are scattered pretty generally through the year, there being a few more during the summer months than during the winter months.

I have prepared the chart with the caption "Winter Typhoid, St. Louis," on the lower half of which are recorded the number of deaths in the months of January, February, March, April, May and December, for the years 1896 to 1903, inclusive. In the line above this tabulation is given the estimate of population found in the testimony of Messrs. Barker and Jordan. Said chart is reproduced on page 7932. I have prepared a

apparent. This is noticed quite effectively in the increase in 1899 of the number of deaths from intermittent fever to 25, the increase being entirely in these younger ages.

The next year, or the year 1900, there were but three deaths from intermittent fever of people 20 years of age or younger, while if we consider the deaths from typhoid fever there is no marked increase in this age and there were no deaths from typhoid fever in that year recorded in the first two columns, those of six months of age and under and those of one year, so that the decrease in the number of intermittent fever deaths for the year 1899, when there were 25, and the year 1900, when there were 10, has not been brought about by transfer of these deaths to the typhoid group. In the other ages the intermittent and typhoid deaths are practically the same respectively, in each of the seven years.

7944 The deaths from typho-malaria follow more nearly the age periods of the typhoid fever than do those of either the intermittent or the remittent fevers. The number of deaths from typho-malaria per year is practically the same during the four years prior to the opening of the canal and the four years subsequent. A greater variation in the age at the time of death occurs in the typho-malaria group than in the typhoid group, the numbers remaining proportionately the same for the respective years.

The deaths from malaria and malarial fever will be seen to be distributed about the same proportionately over the various ages in the different years plotted. There has been a marked increase in malaria and malarial fevers during the past few years. It will be noted that there are about the same number of deaths in the younger ages from malaria or malarial fever during these years and the number of older people is proportionately considerably higher than the mortality in these ages from typhoid fever.

7945 Here again we find the large variation occurring among those under the ages of six months, one year and two and three, the variation being about the same as in the case of

remittent and intermittent fevers. The year 1896 was much higher than any of the other years, although 1897 was also high. It will be noted however, looking at the list in 1896 that 13 of the cases of the congestive fever deaths were under the age of five years, ten of those under one year, and as pointed out before there has been no increase in these ages in the latter period, in the typhoid fever list. With the exception of two years when the congestive fever list was low, the variation was due to the deaths under these younger ages or of quite old people.

In comparing the deaths from congestive fever in St. Louis, with those from typhoid fever, here again the number of deaths from bilious fever is in all cases without any variation in the number, being either in the younger ages or in the older ages, and as mentioned before there has been no increase in the typhoid fever deaths in these ages to correspond with the decline in the bilious fever deaths of those ages. The bilious fever has been considered because no record of it was found in the printed report, and it was thought that possibly it might have been included in the group of "fevers" referred to in this case.

7946 (Witness makes calculation to show the effect of the influx of people to St. Louis on account of the World's Fair.) On the basis of Prof. Jordan's estimates of the population in the city in the year 1903, of 618,500, which is but something less than 60,000 increase in population over 1899, it will be seen that the increase in typhoid has been much more rapid and that it can not be ascribed to any considerable extent to the addition of these or others, who may have been in the city during this time.

7947 This comparison can be shown in another way. Considering the figures given by Professor Jordan for the population of St. Louis, and supposing that the typhoid death rate per 100,000 had remained at 21.6, this population at this rate would have indicated about 130 deaths from typhoid for the year 1903. The actual number of deaths was 281. It can be thus seen that the increase in the typhoid death rate is more than

double in 1903 what is was in 1899, while the population has increased but little over ten per cent. I am familiar with the testimony in regard to the experiment made by Profs. Zeit, Jordan and Russell regarding the longevity of the typhoid bacillus.

7948 I do not think the results of these experiments represent or simulate natural conditions, for the following reasons:

In the first place any sac lodged at one place will receive the influence, if the osmotic conditions are as perfect as is supposed, of sewage which is fresher continually than would be in contact with similar germs passing down the stream. The actual influence, if there is any, of the sac itself is not known. The results vary to some extent from earlier results obtained by various bacteriologists on this same point. There were but three of the series of Professor Jordan's experiments in the drainage canal at either Robey street or at Lockport in which the typhoid organisms were found at all *after* 10 minutes had elapsed, with the exception of one case where it was found ten minutes after inoculation. Of these three cases one is a recorded instance of its occurrence on the 10th day. This has been attributed by Professor Jordan to the fact that bacteria, and especially the typhoid bacteria may be dried against the neck or some part of the sac, and thus be subjected to conditions of greater longevity. This is a possible explanation for this, but there seemed to me to be other explanations. It is a fact, recognized in general, I believe, by bacteriologists that of several forms of microorganisms in the water that one of these forms will apparently mask others, as in the case of experiments with colon and streptococci.

In the earlier periods the colon masks the streptococci so that but few or none are seen. While the streptococci develop much more abundantly and to an extent overgrowing the coli. Later, however, the coli may again appear. Considering this principle it may have been impossible on any of the earlier determinations to have detected the typhoid, although there is no conclusive proof that they were of necessity absent up to

the time of this appearance on the tenth day, and the three typhoid colonies found may be ascribed to the fact that their presence was masked before that date. In regard to the other determinations of Professor Jordan, showing that the typhoid were certainly alive in two cases after the second day, indicates that this germ will live at least this long, but I do not believe that it necessarily shows that they do not live longer.

7949 (Witness gives other reasons.)

I have read the evidence of Profs. Jordan and Burrill upon the colon tests. These tests do not show, by any means, the total elimination of the coli from the waters of the Illinois. Of course there is a reduction, but there is no point reached where there is an elimination of the colon as is shown directly from the tables. These coli determinations are always subject to a good many conditions, especially the presence of streptococci or perhaps even other bacteria present in the water.

7950 These very frequently mask the coli so that any reaction of the coli is not given. In a river water it quite frequently happens that two samples of equal volume, from the same source, will one give the positive, the other the negative reaction for coli, for this reason; so that I do not believe that a negative reaction by any means is indicative of the absence of the coli, especially when it is frequently found in other samples from this same source.

I do not see any indication that the Widal test materially changes the typhoid mortality records of a city. The use of the Widal reaction was begun in the city of St. Louis.

7951 I do not see that any considerable numbers have been either transferred to, or taken from the typhoid list for the city of St. Louis on account of the adoption of the Widal test. I do not believe that any considerable number of deaths have been classed as typhoid since the opening of the drainage canal, which, without the use of the Widal reaction would have been placed in the column entitled remittent, intermittent, typho-malaria, congestive and continued fevers. The variation in the number of people dying from the fevers I have dia-

grammed, has been of people of ages when there are the least number of deaths from fevers and there are more deaths of those at the age of typhoid susceptibility, in the years since 1900 than at any other time during the eight years examined.

CROSS-EXAMINATION, by Mr. Todd:

7952 MR. TODD: I move to strike out all of the evidence of this witness in regard to the records of the mortuary office of the Board of Health of the city of St. Louis, the tables, charts, deductions and conclusions drawn therefrom, for the following reasons:

That the public records of the mortuary office if admissible at all are the best evidence. That it is not the proper way to prove a public record. That the testimony of the witness is not proper and competent evidence to impeach the official published reports of the health commissioner of the St. Louis Board of Health, published by authority of said board, for the reason that the published records of the mortuary office if competent to impeach the authorized published reports of the health department or health commissioner of St. Louis can not be proven in the manner as testified to by this witness, but that the public records themselves are the best evidence and can not be proven in this manner. That it is improper at this time for plaintiff to attempt to impeach the official reports of the health commissioner of the city of St. Louis, which report was relied upon and testified from in the evidence in chief by the complainant's witnesses and made a part of the evidence in chief in this case and is therefore not proper rebuttal and is incompetent and improper evidence. That it is not proper rebuttal after being considered and gone into in chief as the defendants had the right to rely upon the official reports of the

7953 Health Commissioner of the city of St. Louis, published by the authority of the Board of Health of St. Louis and introduced in evidence by complainant, and if said reports were incorrect, inaccurate and unreliable it was the duty of complainant to make such proof in chief and not wait until defendants had rested their case to introduce such improper and

ompetent evidence for the purpose of impeaching the official
orts of the Health Commissioner of the city of St. Louis or
proving the public records of the St. Louis Health Depart-
nt in the manner attempted to be done by the testimony of
is witness. The entire testimony of this witness in regard to
e public records of the Board of Health of St. Louis being in-
mpetent, all conclusions, charts, deductions and opinions are
erefore incompetent, and not proper rebuttal for the reason
at the alleged facts and alleged records which are the basis of
ch tables, charts, deductions and opinions not being legally
oven and legally established vitiate any charts, tables, deduc-
ons and conclusions of this witness and not being proper re-
ttal evidence is incompetent, irrelevant and immaterial.

(See discussion of this objection.)

55 PROF. WM. T. SEDGWICK, recalled in rebuttal by complainant, and examined by Mr. Jeffries:

I think I stated briefly when testifying in chief my rea-
ns for using the percentage mortality basis, but inasmuch as witnesses for the defendants have criticized this
56 method, I desire to state further my reasons and to show by two simple charts that in the case of two cities of
osely similar population, St. Louis and Boston, this method
elds results similar to those which would be obtained by the
eaths per 100,000 basis, that is, the basis of deaths to popula-
on. Both methods are in common use and it is to a consid-
rable extent a matter of choice or taste whether one shall
mploy one method or the other. In favor of the percentage
ortality method is the fact that it eliminates from the prob-
m altogether the question of population, and inasmuch as
opulation in many communities, especially between census
ears, is a most uncertain matter, I personally make frequent
se of the percentage mortality method.

On the other hand there is no doubt that under certain cir-
mstances the other method furnishes more instructive and
ometimes more accurate results. This is particularly true
hen the population is accurately known.

In order, however, to show that in the present case the method of percentage mortality, that is to say the proportion of the typhoid deaths to the total number of deaths is neither inaccurate nor misleading, I have prepared the charts above referred to. One of these, entitled "Typhoid percentage to total Mortality" is constructed upon the basis which I employed in my testimony in chief and upon this chart I have indicated not only the typhoid fever death rate computed in this way for the city of St. Louis, but also for that of Boston, a city of almost exactly the same size.

The second chart, entitled "Typhoid Death per 100,000 Population," is constructed upon the other plan and represents the deaths from typhoid fever in St. Louis and in Boston for the same years covered by the first diagram, namely the ten years, 1884 to 1894. These charts show, I think, clearly the fact that no misleading conclusion could have been drawn from my original testimony, for both demonstrate clearly and to the same effect the essential facts as testified to at that time. These charts are reproduced on pages 7957-8.

7959 (Witness reads quotation, which he gave from memory in his direct examination, as being the statement made by the Rivers Pollution Commission of Great Britain, as follows:)

"There is no river in the United Kingdom long enough to secure the oxidation and destruction of any sewage which may be discharged into it, even at its source."

7960 I have examined the testimony of Profs. Zeit, Jordan and Russell as to their experiment on the longevity of the typhoid bacillus. I should not be able either to form or formulate a comprehensive opinion as to the longevity of typhoid organisms contained in these waters from these experiments alone.

It is clear of course that, as shown in these experiments, the germs survive for certain lengths of time, but I should be unable to conclude from the experiments that under different conditions typhoid fever germs might not survive for longer

times. The experiments appear to me to have been very ingenious and interesting, but not by any means conclusive upon the whole subject of the longevity of typhoid fever germs in moving bodies of sewage or water.

Undoubtedly these experiments were devised, as far as possible, to simulate natural conditions in the water, but in a great deal of experimental work the results of the experimenter falls short of his endeavors. I do not see how it is possible in the present state of bacteriology to devise any series of experiments which shall accurately and completely imitate the infinitely various conditions of running streams, and particularly streams such as the Chicago river, the Chicago drainage canal and the Illinois river, subject as these are,
7961 to an endless variety of alterations, in their physical, chemical and bacteriological conditions.

For example, these experiments were carried on in cold weather I believe, but even if they had been carried on for an entire year, under all actual variations and conditions, they would still in my judgment have been incomplete for the reason that in other years under other conditions organisms as sensitive as typhoid fever microbes are, might have encountered environments which would have materially altered the results. Besides, it seems to me that the conclusions arrived at by these able investigators indicate a shortness of life of the typhoid fever germs which is not in harmony with the longevity naturally deducible from the experience of mankind with epidemics due to typhoid infected waters, and while evidence of this kind is hard to reduce to a strictly scientific basis it has, I believe, nevertheless great value, for the reason that it is the outcome of the experience of the race.

Furthermore, the results of these experiments, broadly speaking, indicate a considerably shorter period of life for the typhoid fever germs in sewage and water than has been found by the majority of previous investigators. My own opinion is

that a greater number of experiments, conducted for a longer time, and under different conditions, would not fail to show that typhoid fever germs may, and do, live in sewage and running streams a very much longer time than was found in these particular experiments.

I should not say that these experiments fail to represent natural conditions, any further than many experiments must necessarily fail to imitate natural conditions. I mean by that, that these experiments were undoubtedly well planned and well conducted, but it is easy to suggest a great number of points in which they do nevertheless fail, the principal failure being to duplicate all the various conditions of the running stream. Some other matters have already been mentioned by witnesses for complainant in rebuttal, such, for example, as the fact that the germs in the several experiments were anchored, so to speak, at fixed points, instead of being allowed to float down the stream with a particular body of water. Any-
7962 one can readily see that this is an unnatural condition, especially in the case of the drainage canal, and the Chicago and Illinois rivers, for the reason that the chemical composition of these bodies of sewage and water is subject to frequent changes. If, for example, the waste from a large industrial establishment should be turned into the Chicago river at any particular moment the water which received it would vary materially in chemical composition from the water just preceding and just following it. For this reason sacs or blocks at anchor are probably exposed to a greater variety of changes than they would be exposed to if they were to float down the stream with one particular body of water.

The sewage discharged from a city at night is a very different body, chemically, from that discharged by day. The sewage discharged during a heavy storm is very different from that discharged in dry weather. Again, the seasonal conditions must be taken into account, and in the case of the Illinois river physical conditions, such as floods in the tributaries, or the overflow of lakes upon these tributaries, bringing in new materials

and a strange bacterial flora. These and many other things which I need not, and could not, mention undoubtedly play a highly important part. The trouble is that in trying to fix the longevity of typhoid fever or any other microbes we are dealing with extremely sensitive and almost infinitesimal organisms which we have only within the last few years learned to recognize at all, and have not yet by any means learned to know thoroughly. I believe, therefore, that while the experiments of the experts for the defense are interesting, ingenious and important in the science of bacteriology, they should not be allowed to have too much weight in determining the issues in this case.

MR. TODD: I move to strike out the last sentence in the witness' answer for the reason that it is not testimony, but argument.

7963 It is my opinion that the results obtained by Profs. Jordan, Zeit and Russell are so far out of harmony with the results of previous investigators and so contrary to the prevailing opinion upon this subject, which forms the basis of the practice of sanitarians and engineers in forming their opinions concerning the availability of polluted streams for drinking and other domestic purposes, as to throw grave doubt upon the results, and therefore upon the conclusions to which these naturally lead.

MR. TODD: Move to strike out the answer for the reason that it is argumentative and is not testimony.

I have examined the testimony of Professor Mason with reference to the effect increased typhoid fever in Chicago would have on typhoid fever conditions in St. Louis, assuming that the germs of this disease pass from Chicago to St. Louis.

7964 Taking into consideration the distance between the two cities and the time required for the passage of typhoid fever germs from Chicago to St. Louis down the drainage canal, the Des Plaines, Illinois and Mississippi rivers, and taking into consideration also the character of the drainage canal and of the Illinois river, and considering also the fact that the

water drawn from the intake at the Chain of Rocks by the city of St. Louis for its public supply is now, and long has been, subjected to extensive sedimentation, I should not expect to find any close correspondence between the details of the typhoid fever curves of the cities of Chicago and St. Louis over such periods.

7965 The tests applied by Professor Jordan and Professor Burrill to the waters of the Illinois river, while they show a very great decline in the numbers of these organisms present in the lower reaches of the river at the times when the specimens examined were taken, in those particular specimens, do not, in my opinion, enable any one to form an accurate opinion as to the presence or absence of typhoid fever germs in the waters of that river at those points.

The reasons for my opinion are, first, that only a comparatively small number of specimens was examined, and from the nature of the case such specimens only imperfectly represent the true and complete character of the stream at all times and all seasons, and, second, that while the colon test is a valuable aid in sanitary water analysis, it is by no means a sure and perfect measure of the presence or absence either of the bacillus coli itself or of the typhoid fever bacillus. It is not a sure and perfect test for the colon bacillus at all times because experiments have shown that this organism sometimes fails to make its appearance in the tests applied, even where it is proven to be present by a further study of the same specimen. And it is by no means a sure test of the presence or absence of the typhoid fever germ, not only for that reason, but also because it is not yet established beyond all reasonable doubt that the life of the typhoid fever germ so closely resembles that of the colon bacillus as to be fairly represented by it under all conditions at all times and all seasons.

I am therefore of the opinion that while the experiments of Professors Jordan and Burrill throw great light upon the pro-

cess of bacterial purification going on in the Illinois river, they do not by any means establish the fact that typhoid fever
7966 is completely or effectually removed from the waters of that river before it empties into the Mississippi at Grafton.

With reference to the charts introduced by Mr. Lochridge, I would say that the typhoid fever deaths taken by themselves alone, show a marked annual increase during the last four years, that is to say since the opening of the Chicago drainage canal. This increase, moreover, is not only considerable from year to year during this period but is much more marked than it was during the preceding period. In fact, during the four years, 1896 to 1899, inclusive, typhoid fever in the city of St. Louis may be said to have been stationary or very nearly so, and not at all excessive, the annual death rate from typhoid fever measured either by percentage mortality or by comparison with the total population having been such as, broadly speaking, prevails only in cities having good water supplies. But during the last four years of the period under consideration, typhoid fever in St. Louis has risen far above this level, until it stands at the end of the period higher than at any time
7967 during the whole period under consideration.

The testimony introduced by the defendants having tended to show a possibility of the transfer of deaths from other diseases, especially remittent, intermittent, typho-malaria, congestive and simple continued fevers into the typhoid group, especially in the latter years under consideration, I have examined with special interest Mr. Lochridge's analysis of these several nondescript fevers, or rather of the deaths attributed to them, and tabulated by him upon his charts; for it was a possibility that some such transfer might in fact have been made. The unquestioned improvement in medical education which has been going on for the last twenty years, especially after the introduction of the Widal test, might conceivably have had some influence in causing such transfer, the effect of which would have

been to increase the number of deaths attributed to typhoid fever in the latter years of the period under consideration. Any such change must, however, of necessity, have been gradual, while in point of fact the increase of typhoid fever in the city of St. Louis was sudden, sharp and has thus far been continuous. In the second place the Widal test, having been introduced by the Board of Health of the city of St. Louis early in the year 1897, should have made its influence felt, if it had any in the direction indicated, previous to the year 1900, but no such influence is visible in the figures compiled by Mr. Lochridge or upon his charts. It is not, however, by any means clear that the Widal test would always tend to increase the total deaths from typhoid fever for, while it unquestionably clears up the diagnosis, and in some cases perhaps leads to the recording of deaths as due to typhoid fever which without its use might have been referred to some other disease, the Widal test works also in the opposite direction, giving negative results in many suspected cases and removing from the typhoid group deaths which without its use might have appeared there. It is important to note that only from five to ten per cent of the specimens sent in by physicians for the Widal test ordinarily prove positive and it is particularly important to note that in the city of St. Louis a large number of cases diagnosed as remittent fever, malaria and typho-malaria fever, the blood from which was subjected
7968 to the Widal test, failed to give any typhoid reaction.

Again, Mr. Lochridge's compilations and charts throw great light upon the whole matter by enabling us to consider the ages of the decedents from the various diseases referred to, as well as the seasons in which they died; and a careful comparison of the incidence of death at the different ages and months, enables one to show beyond doubt that, even if a considerable proportion of the deaths from remittent, congestive and intermittent fevers which occurred previous to the year 1906 were by better diagnosis removed from those groups in the

remaining years, these were not in point of fact transferred to the typhoid group.

As to the matter of season it is important to observe in the first place that Mr. Lochridge's charts indicate a considerable increase in typhoid fever in the city since January 1, 1900, at all seasons, but especially that this increase has been greater in the winter and the spring, than it has in the summer. This is one of the most important facts which I deduce from the charts, for it shows in the first place that the increased number of deaths found in the typhoid group is almost certainly, as proved by this test alone, not due to a transfer of malarial death to the typhoid column since malaria is not prevalent in the winter.

In the second place, this winter increase is extremely important for the reason that during the winter months the Missouri river is a less important factor in the water supply of St. Louis than it is during the summer months; so that this winter increase must have had its origin elsewhere than in the Missouri river.

I will say before leaving them that they appear to me to prove beyond all reasonable doubt that the typhoid fever increase in the city of St. Louis since January 1, 1900, has not been due to any transfer of deaths from remittent, intermittent, congestive, typho-malaria, or simple continued fevers into the typhoid fever group.

One thing more I ought to mention. Mr. Lochridge has made a correction indicated by dotted lines upon some of the charts for the localized epidemic of typhoid fever which occurred in November and December, 1899, and the deaths from 7969 which continued, apparently, into 1900. This epidemic, as I have taken pains to inform myself by inquiry of physicians in different parts of the city and otherwise, was localized in the west central portion of the city, was such that in my judgment could not have been due to a general pollution of the public water supply. I believe that it was due to milk, but I am unable to state this positively.

A comparison of the ages of decedents from these diseases

and of those from typhoid fever makes it perfectly clear that if, as sometimes happens, the number of deaths from a disease in the first group has declined, this cannot be because deaths from this particular disease have been transferred to the typhoid fever group, for the reason that no deaths of corresponding ages can be found in that group.

(Witness makes statement in relation to effect of World's Fair on typhoid conditions in St. Louis.)

7970 In view of these facts, I am of the opinion that no important portion of the increase in typhoid fever in the city of St. Louis since January 1, 1900, can reasonably be attributed to the influx of workmen or others connected with the World's Fair.

7971 I am of the opinion that no circulars issued by any board of health and urging the reporting of *cases* of typhoid fever could have any influence upon the reporting of *deaths* from that disease, for the reason that physicians are legally bound to report deaths anyhow, before a burial permit can be obtained from the Board of Health or other municipal authority. Such circulars in fact sometimes tend to diminish the number of deaths reported from typhoid fever rather than to increase them. I have, indeed, known of a few instances in which a physician had reported a death really due to typhoid fever as due to some other disease because, having failed to report it while living as a case of infectious disease, as required, he feared to incur the displeasure of the authorities if he should report it as a death from that disease and thus possibly subject himself to a summons, a fine, or other penalty.

MR. JEFFRIES: Q. Professor, Dr. Zeit in his testimony along with other witnesses for the defendant attributed extensive destructive effects upon typhoid fever germs in sewage and sewage polluted water to the toxic products of the saprophytes in sewage. State whether or not bacteriologists and epidemiologists agree with him as to these facts?

A. Unquestionably some would agree with him. Others, like myself, do not accept this view and against Dr. Zeit's theory I may quote the following experiment made by myself and one of my students, Mr. D. D. Jackson, as long ago as 1893. In this experiment we undertook to test the very point under consideration.

7972 (Witness describes experiment referred to.)

More recently a similar experiment has been made by Dr. W. H. Horrocks, a well known English bacteriologist, in which Dr. Horrocks found abundant typhoid fever germs in sewage filtered in the same way, after 42 days.

7973 Q. Taking into consideration, Professor, all of the chemical and bacterial data introduced in evidence by the respondents, state whether or not the data so introduced leads you in any way to change your former opinion expressed in this case?

A. I have obtained from these tables and other data a much better knowledge of the process of chemical and bacterial purification going on at certain times and seasons in the Illinois river, but I have failed to discover any reason for changing the opinion which I expressed on my examination in chief a year ago, namely, that the principal part of the increase of typhoid fever in the city of St. Louis since the first of January, 1900, has been due to the presence of deleterious elements contained in the public water supply, and derived from the unpurified sewage of the city of Chicago. The additional information which I have gained on the history of typhoid fever and other fevers in St. Louis, especially during the last year, has only served to strengthen that opinion.

7974 MR. JEFFRIES: I rest.

MR. TODD: I offer in evidence, on behalf of the respondents, in sur rebuttal, the annual reports of the Health Commissioner of the city of St. Louis, published by the Board of Health of the city of St. Louis for the years from 1890 to

1903, inclusive, and ask to have them marked respondents' sur-
rebuttal exhibit "A."

7975 MR. TODD: In behalf of the State of Illinois and the Sanitary District of Chicago, defendants in this case, I rest the case in behalf of the defendants.

THE COMMISSIONER: Gentlemen, my commission for taking the testimony in this case is now closed and further hearing is adjourned without day.